ECET SENIOR DESIGN PROJECT REPORT

Pneumatic PID with Ultrasonic Distance Feedback

For Educational Lab

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Executive Summary

Indiana University–Purdue University Indianapolis (IUPUI) is initiating a new course to the Electrical & Computer Engineering Technology (ECET) Curriculum in the spring of 2019, this course is Advanced Process Controls. The lab curriculum for this course needed a functional application to demonstrate the use of a proportional–integral–derivative controller (PID). The lab location for this course has one important limitation, specifically no use of water; therefore, our design integrates the use of pneumatics. Using the lab's existing Rockwell Automation PLC and software package, this design uses the PLC's PID instruction to maintain an extension length on a pneumatic single acting cylinder. This closed control loop consists of the PLC and analog I/O card, an ultrasonic distance sensor, one pneumatic cylinder for the controlled variable, one pneumatic cylinder as a disturbance, and two Proportion-Air QB1X analog controlled pneumatic solenoids. The final design in summary, uses the ultrasonic sensor to provide feedback to the PID with the current extended length of the pneumatic cylinder. This establishes any error, and the properly tuned PID uses this feedback to respond accordingly to ensure the desired extension length of the cylinder is maintained.

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Revision History

Version	Date	Revised by	Description
1.0	14JAN19	Ron Knight	Initial Version
1.1	13FEB19	Ron Knight	Filled in sections with previous works
1.2	03MAR19	Ron Knight	Updated Section 4.4
1.3	05MAR19	Blaine Wilkin	Updated Section 5 & all verb tense
1.4	02APR19	Basim Al Fuhidah	Checked paper at writing center
1.5	16APR19	Blaine Wilkin	Updated Section 4
1.6	22APR19	Ronald Knight	Corrections from professor Cooney
1.7	24APR19	Blaine Wilkin	Updated conclusion

1. Introduction

IUPUI Electrical Engineering & Technology Department would like to have a device developed as a learning aid to help present a functional PID application. Specifically, this device is to be used in the lab for an ECET course that is being offered as Analog Process Controls. This course began as an option in the ECET elective category during the Spring 2019 semester. It was requested to construct and test the device by a few weeks into the semester. The option that was previously available as a learning aid for this course is a water tank where the water level is maintained using a PID; however, this type of application is not practical in the ECET labs available due to the concern for spilled water being a very common issue. Therefore, a design using a pneumatic device is much more ideal.

1.1. Scope

This project main components will consist of “off the shelf” options from a variety of vendors. Specifically, these main components will be a PLC controller with an Analog I/O card, two electronic pneumatic pressure regulators, two single acting pneumatic cylinders, and an ultrasonic sensor. Additionally, there will be a variety of hardware used for the purpose of mounting and housing the components to create a functional testing pallet to work off of.

The system is a closed control loop to maintain the cylinder’s extension at a certain distance. The input, or set position, will be controlled via a bit value scaled to the desired voltage value or distance setting. The disturbance will be another cylinder mounted in opposition of the controlled cylinder. This second cylinder will be controlled with an additional electronic pressure regulator using PLC logic to simulate different levels of disturbance. The distance sensor will provide feedback to the PLC which will then use the properly tuned PID to adjust the output of the pressure regulator and ensure the extension setting of the control cylinder is maintained.

For this project we have provided instruction to re-create these stations along with the documents needed for testing, repair and maintenance. In addition to the previously mentioned documents, we will also be providing a Lab document for the students that will aid in the implementation of analog sensors and devices while incorporating PID principles.

1.2. Marketing Requirements

1. Reliable and dependable hardware designed for longevity
2. Standardized design capable of duplication
3. Clear and understandable logic
4. Well-commented documentation
5. Clear and understandable learning aid
6. Tested and completed prototype by 7th week of the spring semester 2019
7. Well-managed budget

Marketing Requirements	Engineering Requirements	Justification
1, 2, 7, 8	Use as many school resources readily available	This will reduce cost and lead time on parts
2, 3, 4	Clear documentation for assembly and specific PLC Logic design	Clear documentation will assure this is usable as a lab in the future
1, 2	The hardware system should be capable of interfacing with PLC analog I/O components	The purpose of the lab is to observe analog devices in conjunction with a PID
6	The pneumatic cylinder position will be disturbed using a second automated pneumatic cylinder.	Customer specified that a disturbance be automated
1, 2	An ultrasonic sensor will provide feedback to the PLC/PID via current (4-20mA)	Customer specified the feedback sensor type
2	Capable of fitting in the existing storage space	Limited storage options

2. Specification Requirements

2.1. Customer Design Specifications

- Use pneumatic controller from Proportion-Air
- Use pneumatic cylinders
- Overall design dimensions must fit into a common work station in ECET lab
- Use Allen Bradley PLC system with Analog card
- Use RS Logix 5000 PLC programming software
    - Use the PID instruction for the control system
- Use devices which can represent Analog Current and Voltage capabilities
- Use an ultrasonic sensor for feedback

2.2. Build Specifications

- PLC
    - Allen Bradley- L32E PLC controller
    - Allen Bradley- 1769-PA2 (24Vdc) Power Supply
    - Allen Bradley-1769-IA16 Digital Input Module
    - Allen Bradley-1769-OW16 Digital Relay Output Module
    - Allen Bradley Analog I/O- 1769-IF4XOF2
- Analog (0-10v) pneumatic controller- QBT Proportion-Air QBX1 Series Pressure Regulator p/n: QB1XANEEZP100PSG
- Pneumatic Controller-6ft cable for QBT
- Pneumatic single acting cylinders- 3/4" Air Cylinder Bore Dia. with 6" Stroke Stainless Steel, Front Block Mounted Air Cylinder p/n: 0.75BFNSR06.00

- Ultrasonic Sensor, 508mm Detecting Distance, 40mA Max. Load p/n: VM1CAQ
- Pneumatic fittings and hose
  - 1/4in NPT female connectors
  - 1/8in NPT female connectors
  - 1/8in pneumatic tubing 3ft per station
  - 3-way connector (T)
- House Air
- Standard Wire Terminal Block
- Plexiglas safety guard
- Miscellaneous mounting hardware/platform materials

3. High Level Design

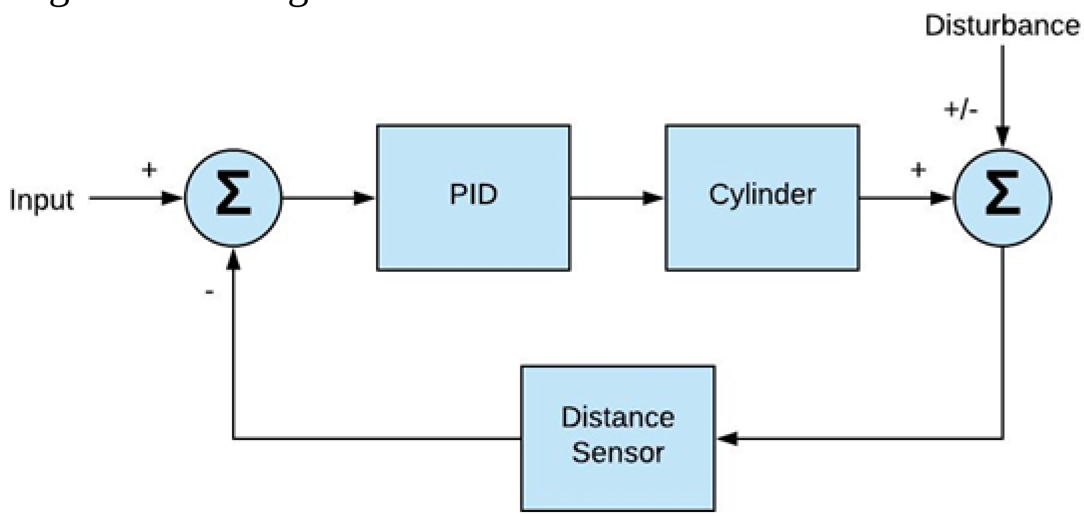


Figure 3-1 High Level Control Loop

Input: This will be the desired preset position of the pneumatic cylinder

PID: This will receive the desired input and the actual input of the cylinder, respond to the disturbance, and recalculate the necessary voltage output to the controller to maintain the desired position.

Controller/Cylinder: Receives the necessary Analog voltage setting to achieve the desired cylinder position.

Disturbance: This will be the cylinder manipulated via a manual pressure regulator feeding another pneumatic cylinder creating an error on controlling cylinder

4. Low Level Design

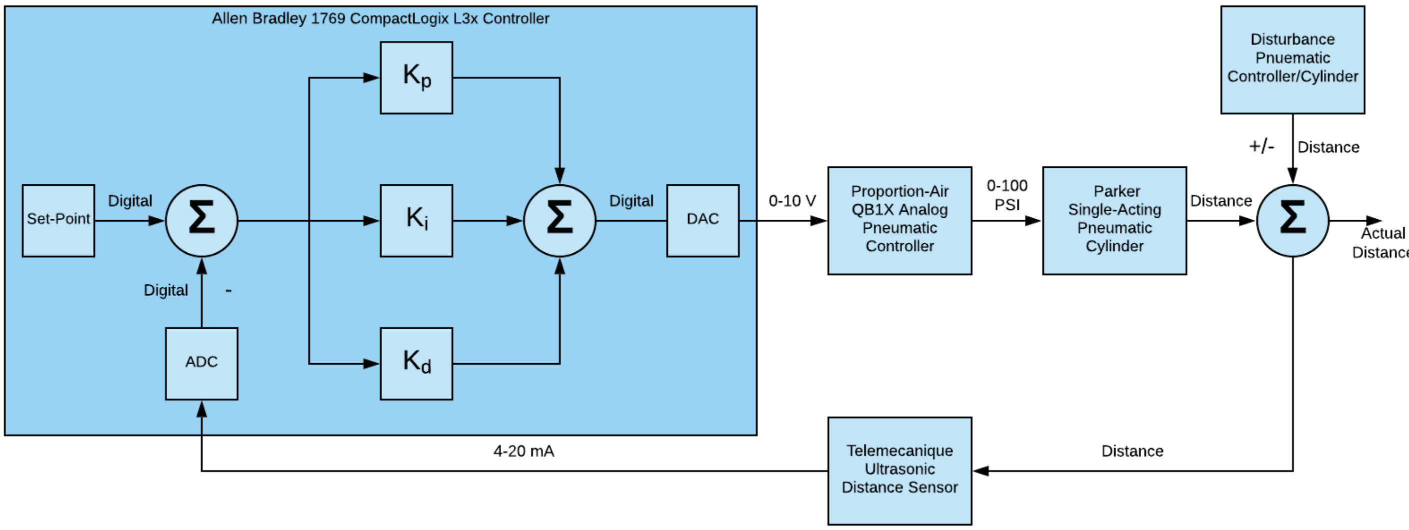


Figure 4-1 Low Level Control Loop Diagram

4.1. Design Decisions

I. Overall Design:

- *Disturbance:* The original design concept for this project was to have the pneumatic cylinder rotate around a horizontal central axis and have gravity be the disturbance. At the request of the customer this has been modified to be a stationary cylinder with a second cylinder providing the disturbance. The second cylinder will be placed in the opposite direction of the main cylinder. This will allow a more controlled disturbance and reduce the overall footprint of the station. This design will control the secondary cylinder with an additional electronic pressure regulator, which will be programed in the PLC logic to create a pattern of disturbance levels.
- *PID:* The customer already owns several PLCs that can perform the function of a PID. Another option for this functionality is an analog PID controller. These controllers have a slower response time and would cost more than the existing solution. Therefore, the decision was made to use the customers PLC's as a digital PID.
- *Mechanism:* Since the customer wants to use pneumatics, instead of liquid, to visualize a control loop a linear pneumatic cylinder will be used due to its simplicity. Any cylinder with a sufficient stroke would be acceptable for this project. It was discussed with the customer that a six-inch stroke would be a good size for a visual aid.

II. Inputs: For a control loop to work properly it needs several inputs. The loop for this system requires two inputs: a reference input and a feedback input. The reference input is the state that we want the system to achieve, and the feedback is the error of the system from its reference state.

- *Reference*- This will be provided via a scaled current input to the PLC logic and entered as a bit value, this will be the PID's set point (Sp)

- *Feedback*- Due to the requirements outlined by the customer, an ultrasonic sensor will be used for the distance feedback to the system, this will be the PID's process variable (Pv).

III. **Outputs:** There will be 2 outputs from the PLC, one output to each electronic pressure regulator. Regulator 1 will be controlled by the PID as the control variable (Cv), and Regulator 2 will be controlled via a prewritten pattern of disturbance in PLC ladder logic.

IV. **Ultrasonic Sensors:** Several different distance sensors where ranked (1-5) in four different criteria (Appendix A Table A-1). The final decision was made for the Telemecanique due to the higher score.

V. **Pressure Controller:** Only one device was considered due to the company giving the school a deep discount.

VI. **PLC:** Only one device was considered due to the customer already owning several which have all necessary capabilities for this System.

VII. **Cylinders:** It was decided to use a cylinder with a ¾ in. bore. This gives the system a maximum linear force of about 44 pounds if used with a 100 PSI air source. This is a good middle ground between too much and too little force as the next nominal sizes would net approximately 28 or 60 pounds of force. Also, as discussed with the customer, a six-inch travel distance will be used. Two cylinders were ranked (1-5) with two different criteria (appendix A Table A-2). The final decision was made for the Parker 20XT39.

4.2. Software Design

Figure 4-2 PLC Program Ladder Rung 0 PID

Rung 0- The PID instruction parameters are set via the property settings of the instruction Figure 4-3 and Figure 4-4 below.

- *Set Point (SP)*- Manually input to cause system to move.
- *Process Variable (PV)*- actual distance the cylinder is extended via the input from the Ultrasonic Sensor (Ultrasonic Sensor Input 4-20mA) displayed as scaled bits (0-6000).
- *Control Variable (CV)*- output to the pneumatic controller (0-10Vdc) displayed as a percentage.

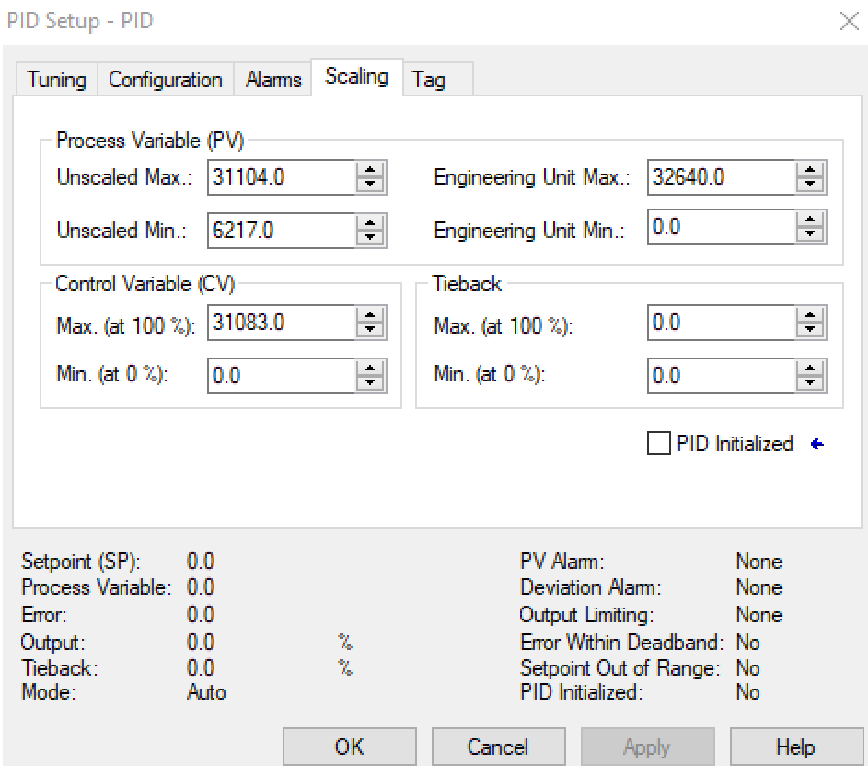


Figure 4-3 PID Scaling Parameter Configuration

Figure 4-3 displays the ability to scale the input from the Process Variable (PV) and Control Variable (CV). These configurations can be accessed via the properties of the PID instruction.

- For this design the input from the Ultrasonic Sensor will be received as a bit value range of 6217- 31104
  - the PLC has an actual range of 0-32640 bits & 0-21mA, but receives only 4-20mA from the sensor therefore 6217-31104 bits.
- The Control Variable will be configured to a range of 0-31083 bits which will be internally scaled to an output of 0-10Vdc
  - the PLC has an actual output range of 0-32640 which is 0-10.5Vdc; however, the pneumatic controller’s range is 0-10Vdc; therefore, 0-31083 bits.

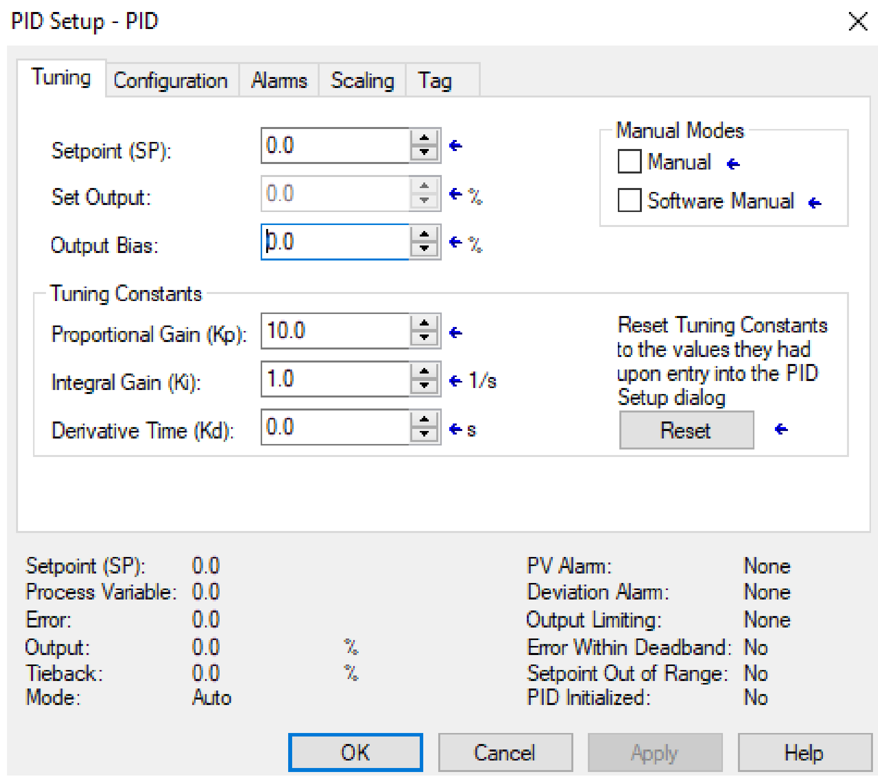


Figure 4-4 PID Tuning Parameter Configuration

Figure 4-7 displays the ability to manually enter the desired tuning parameters for the PID. Specifically, the Proportional Gain (Kp), Integral Gain (Ki), and Derivative Time (Kd). The Set point (SP) will be an input from the potentiometer range between 0-10Vdc scaled to 0-32640 bits.

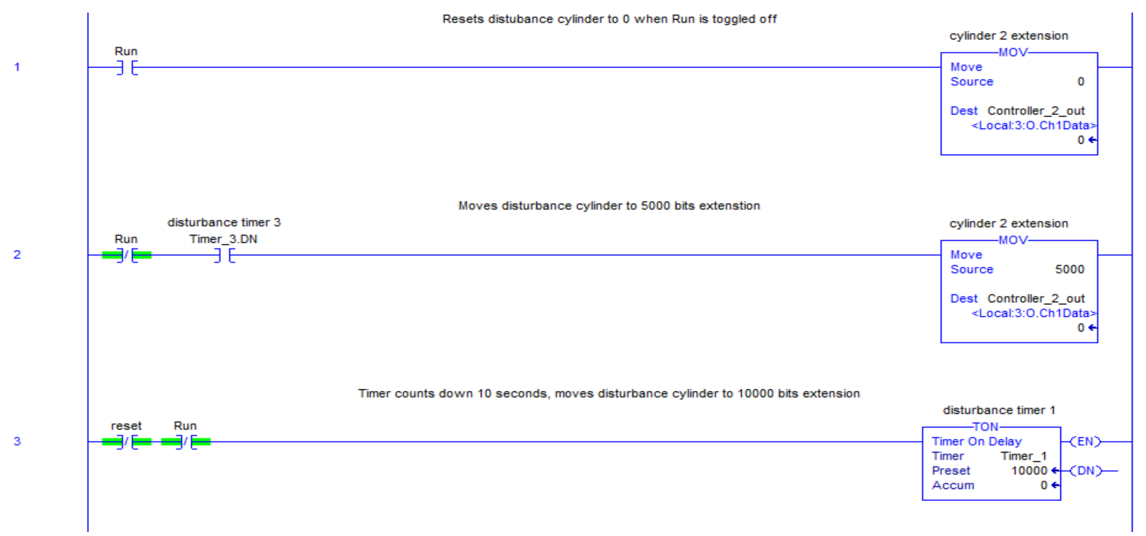


Figure 4-5 Automated Disturbance Ladder Logic

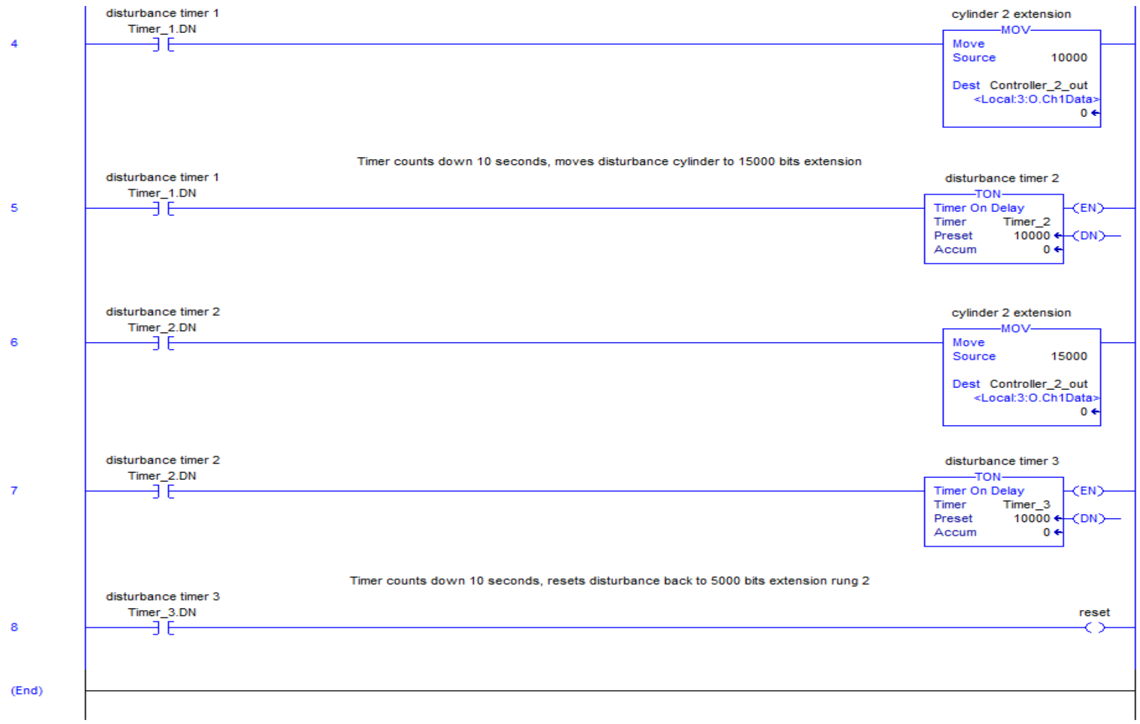


Figure 4-6 Automated Disturbance Ladder Logic

Figure 4-5 through 4-6 displays the logic used to automate the disturbance,

- *Rung 1*-has a universal control tag “Run” which can be toggled at any any point in the program to stop the automation cycle and return cylinder 2 to the fully retracted position.
- *Rungs 2,4,6*- use a move instruction to move a desired bit value to controller 2.
- *Rungs 3,5,7*-use on-delay timers between each move instruction to initiate the move from the disturbance cylinder to more or less pressure against cylinder 1.
- *Rung 8*-resets the disturbance cycle back to the initial move instruction and restarts the logic.

Name	Alias For	Base Tag	Data Type	Description
Controller_1_out	Local:3:O.Ch0Data(C)	Local:3:O.Ch0Data(C)	INT	cylinder 1 extension
Controller_2_out	Local:3:O.Ch1Data(C)	Local:3:O.Ch1Data(C)	INT	cylinder 2 extension
PID_1			PID	
reset			BOOL	
Run			BOOL	
Sensor_in	Local:3:I.Ch1Data(C)	Local:3:I.Ch1Data(C)	INT	distance feedback
Timer_1			TIMER	disturbance timer 1
Timer_2			TIMER	disturbance timer 2
Timer_3			TIMER	disturbance timer 3

Figure 4-7 Local Program Tags

Figure 4-7 displays an example program tags and the alias’ necessary for this labs function

4.3. Bill of Materials

Description	vendor Part #	vendor	price	Order quantity	total cost
Wood, 12"x36"x0.75"	N/A	Lumber Yard	$10.00	6	$60.00
QBX Series Pressure Regulator, Single Loop, Aluminum Body, 1/8 NPT Pneumatic Connection 0 to 10 vdc Input Signal, 0 to 100 psi Gage Pressure Output, 0 to 10 vdc Monitor Signal	QB1XANEEZP100PSG	Proportion Air	$175.00	12	$2,100.00
Cable, 6 Feet, For QBT	QBT-C-6	Proportion Air	$16.50	12	$198.00
3/4" Air Cylinder Bore Dia. with 6" Stroke Stainless Steel , Front Block Mounted Air Cylinder	20XT39	Grainger	$56.91	12	$682.92
Plastic Rectangular Ultrasonic Sensor, 508mm Detecting Distance, 40mA Max. Load	1EXB5	Grainger	$147.50	6	$885.00
Right Angle Proximity Sensor Mount, Zinc, For Use With 18mm Dia. Proximity Sensor	5B429	Grainger	$4.74	6	$28.44
Cordset, End 1 Number of Pins: 4, End 2 Gender and Plug End: Bare Wire, End 1 Keyway: Single	19MJ17	Grainger	$16.10	6	$96.60
Standard Polyurethane Tubing, 1/8" Outside Dia., 1/16" Inside Dia. (100 ft.)	4HL93	Grainger	$16.48	1	$16.48
1/8" Brass Male Adapter, Brass (pneumatic fitting)	36W987	Grainger	$2.05	37	$75.85
1/8" Plastic Union Tee, White/Gray	36W731	Grainger	$3.58	12	$42.96
1/8" Plastic Plug, Red (Pkg. of 10)	1PFD4	Grainger	$18.11	1	$18.11
Conduit Hanger, 1/2" Nominal Conduit/Pipe, Stainless Steel	36HX14	Grainger	$4.18	24	$100.32
6-Pole Phenolic Terminal Strip, 15 Amps, 300VAC	6ZEF6	Grainger	$7.87	6	$47.22
Wood Screw, Rnd, #8, 3/4in, SST, Phil (Pkg. of 100)	31JG34	Grainger	$14.42	1	$14.42
#8x3/8" O.D., Flat Washer, Stainless Steel, 316, Plain (Pkg. of 100)	6UKX0	Grainger	$9.42	1	$9.42
Steel Industrial Coupler Plug	30N280	Grainger	$2.14	1	$2.14
1/4"-28 Hex Nut, Plain Finish, 18-8 Stainless Steel, Right Hand (Pkg. of 50)	22YK25	Grainger	$2.12	1	$2.12

Description	vendor Part #	vendor	price	Order quantity	total cost
1/4"x1" O.D., Fender Washer, Steel, Low Carbon, Zinc Plated (Pkg. of 50)	4ARW3	Grainger	$2.70	1	$2.70
Fork Terminal, Red Vinyl, Butted Seam, 22 to 16 AWG, 100 PK	5WHE4	Grainger	19.03	1	19.03
1/8" Dia. Cable Clamp, 6/6 Nylon, Black, 1/2" Width (Pkg. of 100)	14X933	Grainger	$6.75	1	$6.75
Overall Total (6 stations)	N/A	N/A	N/A	N/A	$4,182.50
Total Per Station	N/A	N/A	N/A	N/A	$697.08

5. Test Methodology & Results

5.1. Methodology

The four main deliverables for this project are the stations, the lab documents, and the build & troubleshooting documents. Once built, all stations were connected to a PLC and 100 PSI air supply. Each PLC was programmed with the known good RS Logix program. Once running each station was calibrated by aligning the ultrasonic sensors so that each reads the same bit value. After calibration all six stations where run in an automated disturbance mode for a half hour and monitored for issues. The lab documents were tested by giving them to volunteer students to carry out. While the students carried out the procedures they were asked to take notes on what works, does not work, or needs more clarification. Once the procedures were completed the students were asked to fill out a small survey to provide more specific feedback. The build and test documentation was created by documenting the dimensions and each step during the building and testing of the first station. Once this was completed the documents were drafted. The testing of these documents were carried out by students on the remaining five stations. During this time notes were taken to note changes required to be applied to the final documents.

5.2. Results

Individual Stations

- When testing if the air supply was adequate we ran in to no issues with the devices split at the air source.
- There were no faults or issues during the running of the automated disturbance program on all six devices.
- During the calibration of the ultrasonic sensors, each sensor was adjusted slightly to allow each station to use the same scaling factors.
- While moving the stations in various orientations there were no noticeable differences.

Lab Documentation

- The students had issues getting output or input from the analog card due to not having a step to enable the I/O in the software.
- There was a problem with understanding what each scaling parameter was doing so a reference to the manual section on scaling was added.
- One of the students was confused regarding the difference between the Control Variable (Cv) and the Process Variable (Pv). This student was not enrolled in the course. Students enrolled in this course will be taught this prior to the lab.
    - Initially all gain settings are zero. This causes the loop to do nothing which caused the students confusion. A note was added to make the proportional gain greater than 0 before starting.
- Not all PLCs in room ET210 have a power supply that has the 24V rail. A note was added to ensure use of appropriate PLC or to use an external DC power source.

Build & Test Documentation

- After building the remaining five stations following the build documents each station worked immediately with slight variations between each.
- Both build & test documentation was given to the lab supervisor for review. No issues were reported.

6. Conclusion

6.1. Recommendation

To expand functionality and usability as an educational system it is recommended to calculate the transfer functions of the various components and the system as a whole. While this was out of scope for this project it would allow the students to have a mathematical baseline for what an optimal system response could look like. Also there can be further labs created from these systems.

6.2. Individual Assessment

To begin this project, the first challenge that we faced was to design a clear and understandable system to demonstrate a functional closed loop control system, and act as a learning aid for the "Advanced Process Controls Course" being introduced to the ECET curriculum. Some tools necessary for this project were already present, such as the PLC system and software, which set us up with a solid foundation to kick this project off. Using an electronic pneumatic controller from Proportion-Air was requested, which became a fantastic component to achieve our overall goal. Aside from some other common devices and wiring we were all set to go. Our initial design was focused around using gravity to create our disturbance against our controlled cylinder, which we each believed would provide little error and provide a poor example of this concept over all. After some discussions with faculty, and sharing everyone's ideas, we concluded that the best option could be to automate our disturbance using an additional pneumatic controller and cylinder, assuming we could design this within our designated budget. With some generous discounts offered by Proportion-Air we were in fact able do so, and our final product gives the functionality to create any pattern of disturbance that is desired, which will maximize the learning experience of this design.

When this project initiated in the fall of 2019, several challenges were immediately present for each of us, while we shared some of them, we each carried our own different challenges as well. The challenge that we all shared was the functionality of a PID, we have each applied this concept minimally in our courses to date. However, a clear real-life application of this concept was still missing. Aside from this challenge, each of our own experiences in the EET curriculum brought something different to the table. As this project developed, we each had our moments to highlight our best. We each took our own learning experiences from this project. We also shared several experiences, such as; the ability to see a project develop, apply teamwork to make it happen, and present a final product that meets or exceeds the needs of our customer.

Notes

References

Title	Source	Comment
Logix 5000 Controller General Instruction Reference Manual	Allen Bradley	PLC Manual
Compact 8-Bit Low Resolution Analog I/O Combination Module User Manual	Allen Bradley	Analog Card Manual
QB1X & QB2X Installation and Maintenance Instruction Guide	Proportion-Air	Pneumatic Controller Manual
NFPA 70, National Electric Code (NEC) 2017	National Fire Protection Association	Table B 310.15(B)(2)(3)

Appendix A Decision Matrices

	Low Cost	Durability	Ease to Implement	Repurpose Ability	Total
Weighting	5	4	3	2	
Pepperl+Fuchs 261246	2	5	5	5	55
Telemecanique 1EXB5	3	5	5	5	60
HRLV-MaxSonar EZ4	5	2	1	1	38
Sharp GP2Y0A41SK0F	5	2	5	4	56

Table A-1 Distance Sensor Decision Matrix

- *Cost*- Lower cost is preferred; each device was ranked from cheapest to most expensive.
- *Durability*- Pepperl+Fuchs & Telemecanique are industrial level devices so they are built with durability in mind while HRLV & the Sharp are more hobbyist level.
- *Repurpose Ability*- Pepperl+Fuchs, Telemecanique, and Sharp could easily be moved to a new lab or demonstration with little effort. HRLV would require reprogramming and familiarity with said programing.

	Low Cost	Ease to Implement	Total
Weighting	5	4	
Speedaire 5MMG8	5	3	37
Parker 20XT39	4	5	40

Table A-2 Cylinder Decision Matrix

- *Cost*- Lower cost is preferred; each device was ranked from cheapest to most expensive.
- *Ease to Implement*- The Parker is a single acting cylinder, this means we would only need to implement a single pressure controller.

Appendix B CAD Drawings

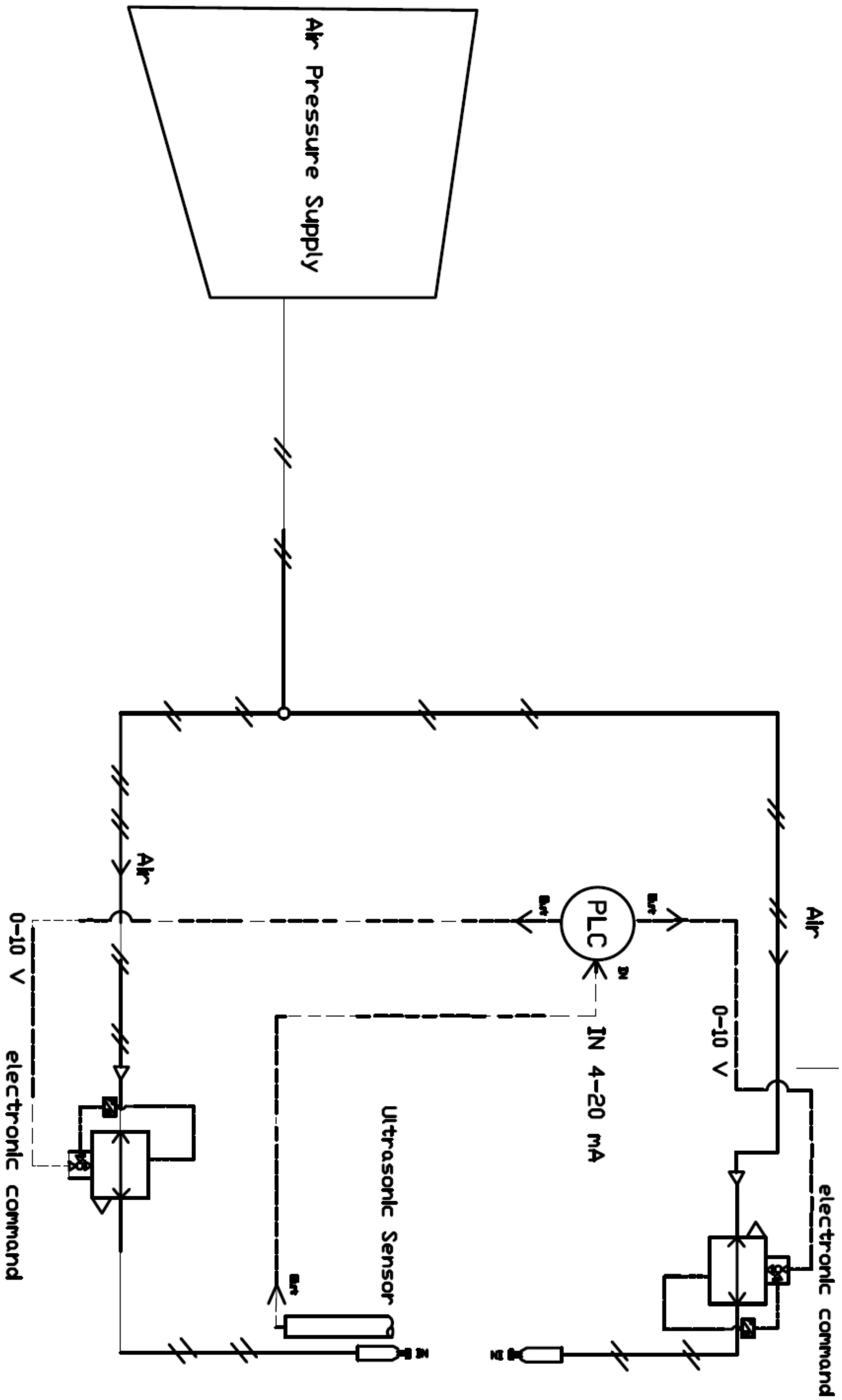


Figure B-1 Piping & Instrumentation Diagram

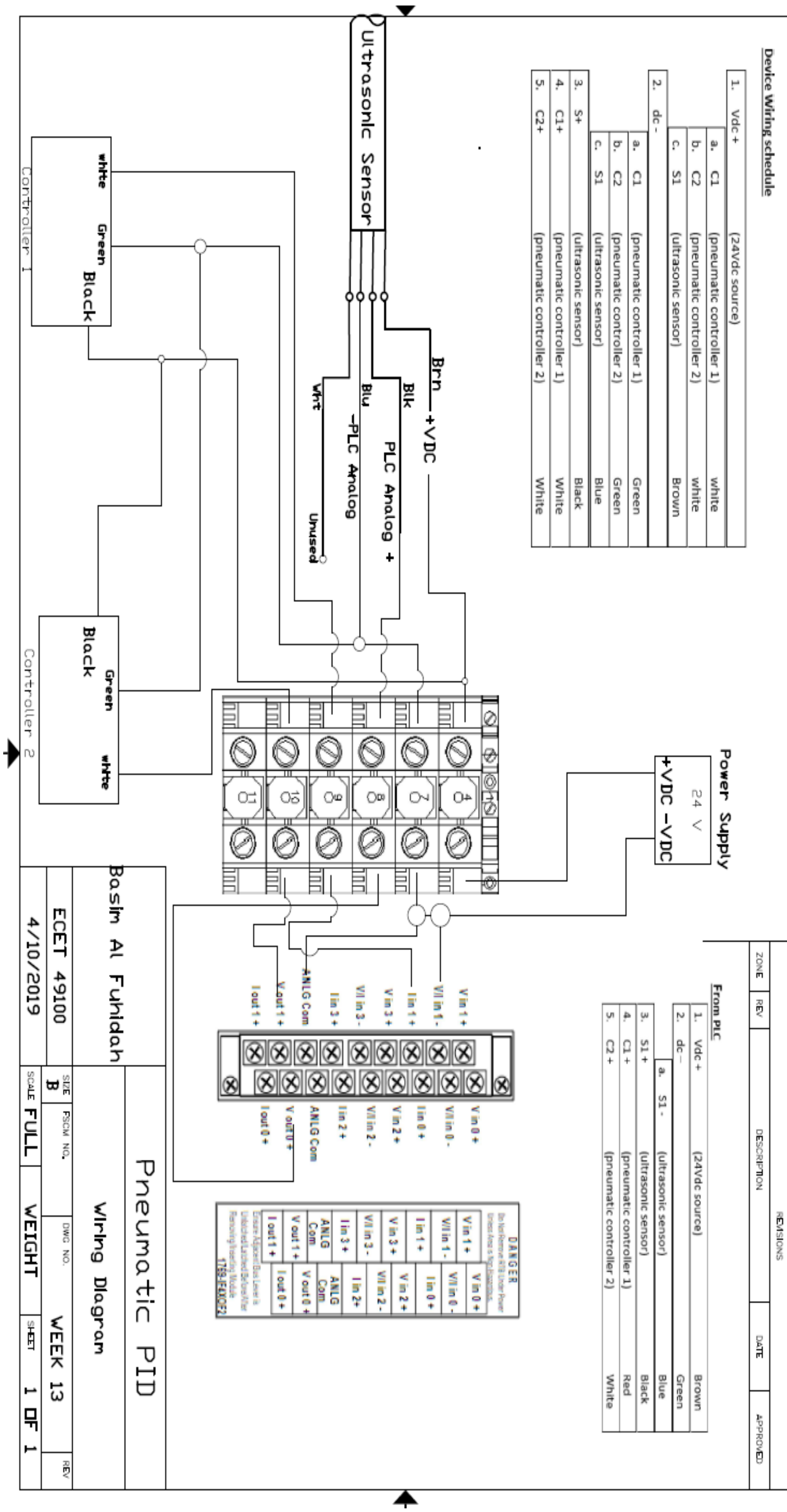


Figure B-2 Wiring Diagram

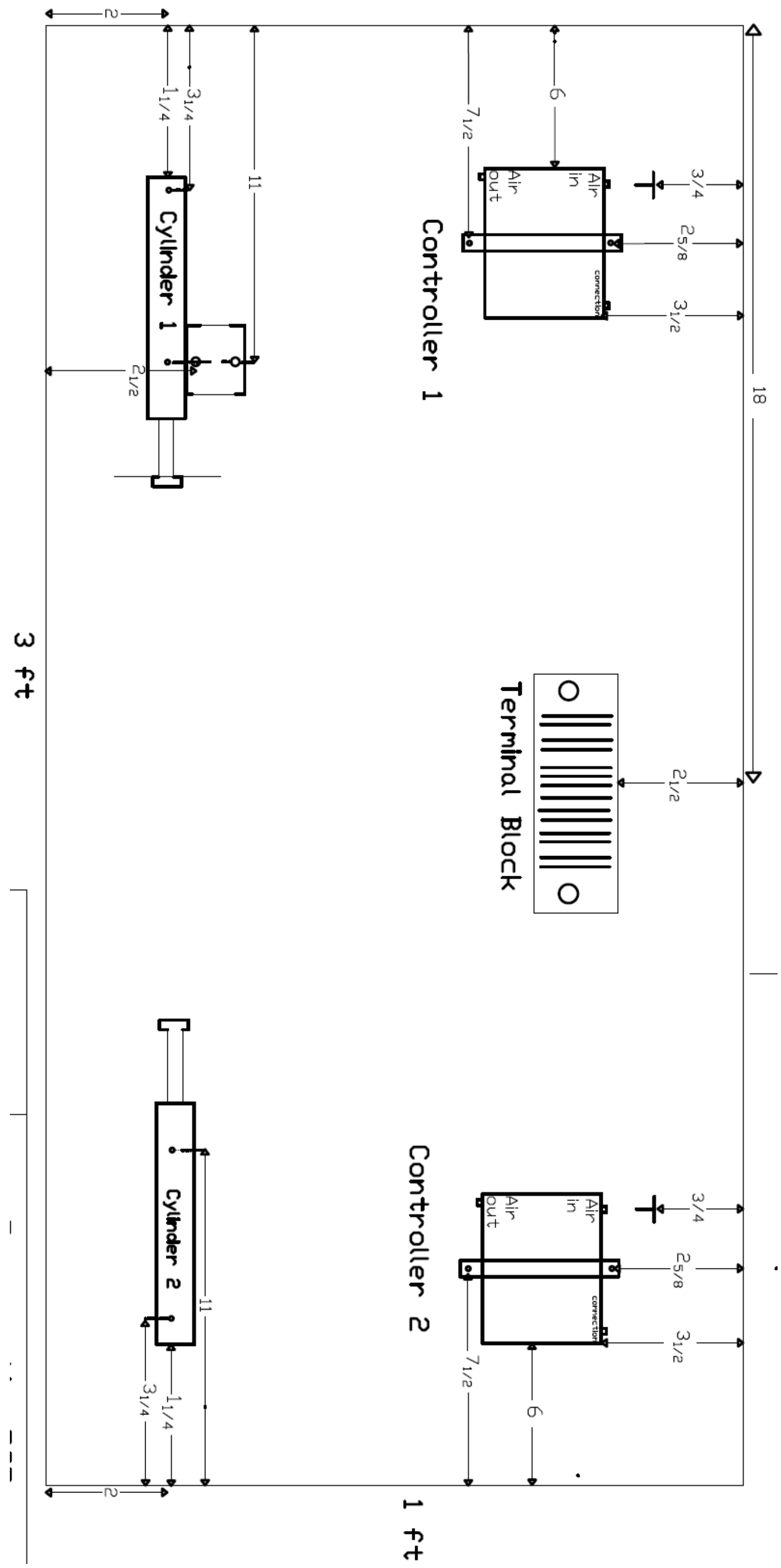


Figure B-3 Dimensional Diagram

Appendix C Build Procedure

SAFETY PRECAUTIONS

1. Currents between 100 and 200 mA can be lethal. Follow appropriate electrical safety precautions.
2. Do not place objects between the cylinder pistons. Each cylinder is capable of approximately 44 ft·lbf.

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

TOOLS

1. Box Wrench Set
2. Screwdriver, Philips, #2
3. Wire Strippers
4. Side Cutters
5. Tape Measure

PARTS & MATERIALS

Description	Vendor	Vendor Part #	Amount
Plywood, 12"x36"x0.75"	Lumber Yard	N/A	1
MDF Board, 4⅛"x1⅜"	Lumber Yard	N/A	1
QBX Series Pressure Regulator	Proportion Air	QB1XANEEZP100PSG	2
Cable, 6 Feet, For QBT	Proportion Air	QBT-C-6	2
3/4" Air Cylinder	Grainger	20XT39	2
Ultrasonic Sensor	Grainger	1EXB5	1
Sensor Mount	Grainger	5B429	1
Sensor Cable	Grainger	19MJ17	1
⅛” Polyurethane Tubing	Grainger	4HL93	6’
⅛" Brass Male Adapter	Grainger	36W987	6
⅛" Plastic Union Tee	Grainger	36W731	2
⅛" Plastic Plug	Grainger	1PFD4	1
Conduit Clamp	Grainger	2KWP4	4
Terminal Strip	Grainger	6ZEF6	1
Wood Screw, Rnd, #8, 3/4in	Grainger	31JG34	14
#8x ⅜" O.D., Flat Washer	Grainger	6UKX0	14
Steel Industrial Coupler Plug	Grainger	30N280	1
¼"-28 Hex Nut	Grainger	22YK25	2
¼"x1" O.D., Fender Washer	Grainger	4ARW3	2
⅛" Dia. Cable Clamp	Grainger	14X933	10
Fork Terminal	Grainger	5WHE4	2
PLC connector	IUPUI	N/A	1

NOTES: Full part descriptions and details can be viewed on the full bill of materials.

PROCEDURE

1. Preliminary

a. If desired, prime/paint/stain wood and allow time to dry.
b. Place board on sturdy surface in a horizontal orientation.

2. Secure Devices to Board

a. Secure Cylinders

i. Mark the screw holes on the wood with pencil in four locations.

1. 2” from bottom and 3 ¼” from the left
2. 2” from bottom and 11” from the left
3. 2” from bottom and 3 ¼” from the right
4. 2” from bottom and 11” from the right

NOTE: See Figure 1 for exact board layout and hole placement.

CAUTION: Be careful not to over tighten screws

ii. Use ¾” screws and ⅜” O.D. washers to secure four conduit clamps to board at the locations marked in step 2.a.i.

iii. Place cylinders into conduit clamps with pistons facing each other and vent port facing up.

Note: Leave rubber caps on cylinders

iv. Ensure end of cylinders are 1 ¼” from board edge and cylinders are 6” apart.

v. Use included nut and bolt to tighten conduit clamps until cylinders are immobile.

vi. Verify cylinders are still 1 ¼” from board edge and cylinders are 6” apart. If not loosen nut and bolt and repeat from step 2.a.iv.

NOTE: To ensure alignment, pull one of the two cylinders’ piston all the way out and ensure that it meets the opposing cylinder’s piston.

b. Secure Controllers

i. Place the two controllers on the board with the connector on the right side and facing the top of the board in two locations with two 2” pieces of ⅛” polyurethane tubing underneath the controllers lengthwise.

1. 6” from the left and 3 ½” from the top
2. 6” from the right and 3 ½” from the top

NOTE: See Figure 1 for exact board layout and controller placement.

ii. Place brackets over each controller in the middle of the controller.

iii. Verify controllers are still in correct positions.

iv. Use ¾” screws and ⅜” O.D. washers to secure each bracket to the board.

c. Secure Terminal Strip

i. With Pencil, mark point on board at 18” from the edge and 2 ½” from the top.

ii. Align Terminal strip top edge horizontally with the previously marked point.

iii. Use two ¾” screws to secure Terminal strip.

d. Secure Sensor and Bracket

i. Line up sensor bracket flush with cylinder 1 conduit clamp and exhaust port as shown in figure 6

ii. Use two ¾” screws and ⅜” O.D. washers to secure bracket to the board.

iii. Screw one of the included plastic nuts onto the sensor

iv. Place sensor through the bracket hole with the connector facing the top of the board.

v. Use remaining plastic nut to secure sensor to bracket.

e. Secure Pneumatic Tees

i. Align each of two pneumatic tees with the single port facing the controllers and the top flat edge ¾” from the top of the board.

ii. Use two ¾” screws to secure pneumatic tees to board.

3. Install Pneumatics

a. Using supplied Loctite, Install included air filters to the input of the two controllers.
b. Install ⅛" Brass Male Adapter into each of the six ports.
   i. Both controller inlet ports
   ii. Both controller outlet ports
   iii. Both cylinder inlet ports
c. Cut appropriate lengths of the ⅛" Polyurethane Tubing and connect devices.
   i. Each cylinder to their corresponding controller output
   ii. Each controller to their corresponding tee
   iii. Each tee together
d. Secure tubing to board with ⅛" Dia. Cable Clamp.

   Note: Recommended tubing layout and securing points can be seen in figure 3.
e. If this is the first station, install a ⅛" Brass Male Adapter into the quick fitting and adequate tubing to reach between the air supply and one port of the tee adapter.

4. Wire Devices

Note: Full wiring diagram can be seen in figure 2.

a. Connect and secure each cable to their respective devices.
   i. Push connector into each controller and tighten screw in center of connector.
   ii. Push connector onto ultrasonic sensor and tighten connector collar.
b. Lay each cable out in an orderly fashion to reach the terminal block.

   Note: See figure 3 for recommended cable layout.

   Warning: Ensure cables will not interfere with ultrasonic sensor flag.
c. Cut excess cable from each device and set aside for future use.
d. Strip approximately six inches of insulation from each cable exposing wires inside.
e. Strip approximately ½" from each wire.
f. Wire ultrasonic sensor to bottom side of terminal block.
   i. Brown wire to first terminal from the left.
   ii. Blue wire to second terminal from the left.
   iii. Black wire to third terminal from the left.
   iv. White wire is unused.
g. Wire left controller (controller 1)
   i. Black wire to first terminal from the left.
   ii. Green wire to second terminal from the left.
   iii. White wire to fourth terminal from the left.
   iv. Brown, red, and blue are unused.
h. Wire Right controller (controller 2)
   i. Black wire to first terminal from the left.
   ii. Green wire to second terminal from the left.
   iii. White wire to fifth terminal from the left.
   iv. Brown, red, and blue are unused.
i. Using one of the controller cut cables from step 4.c. strip approximately six inches from each end and ½" from each wire.
j. Connect cable from step 4.i. to top of terminal block.
   i. Brown wire to first terminal from the left.
   ii. Green and Blue wire to second terminal from the left.
   iii. Black wire to the third terminal from the left.
   iv. Red wire to fourth terminal from the left.

v. White wire to fifth terminal from the left.
vi. sixth terminal is unused.

Note: Terminal connections can be viewed in figure 4.

k. Connect Terminal Connectors to the green and brown wire.

l. Connect system to PLC terminal block.
   i. Blue wire to V/I in 1-
   ii. Black wire to I in1+
   iii. Red wire to V out 0+
   iv. White wire to V out 1+

Note: PLC connections can be seen in figure 5.

m. Label each wire in accordance with table 1.

5. Test System

a. Load and run supplied program to verify proper operations. If trouble occurs, follow supplied troubleshooting procedure.

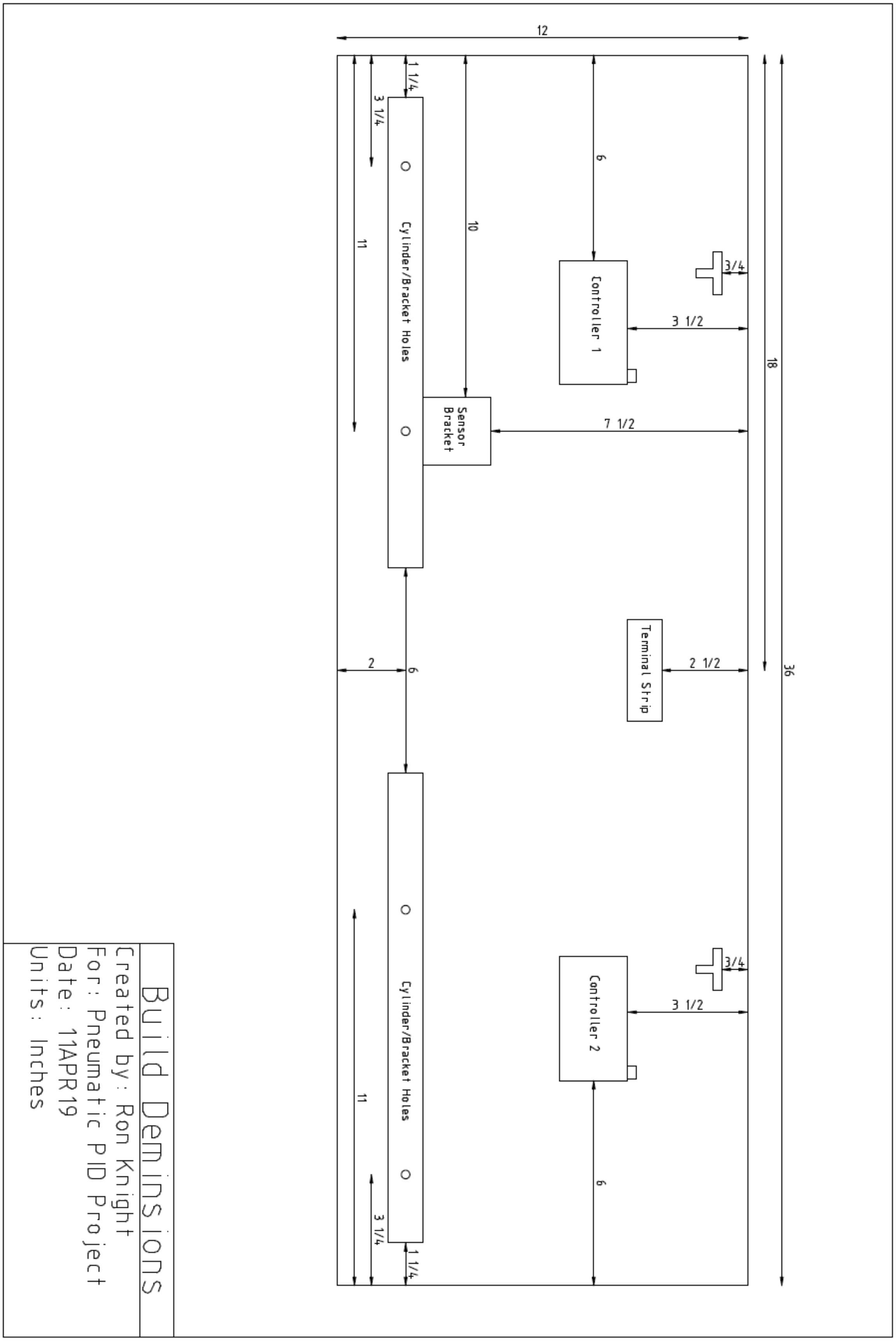


Figure 4 Build Dimensions

Figure 5 Built System

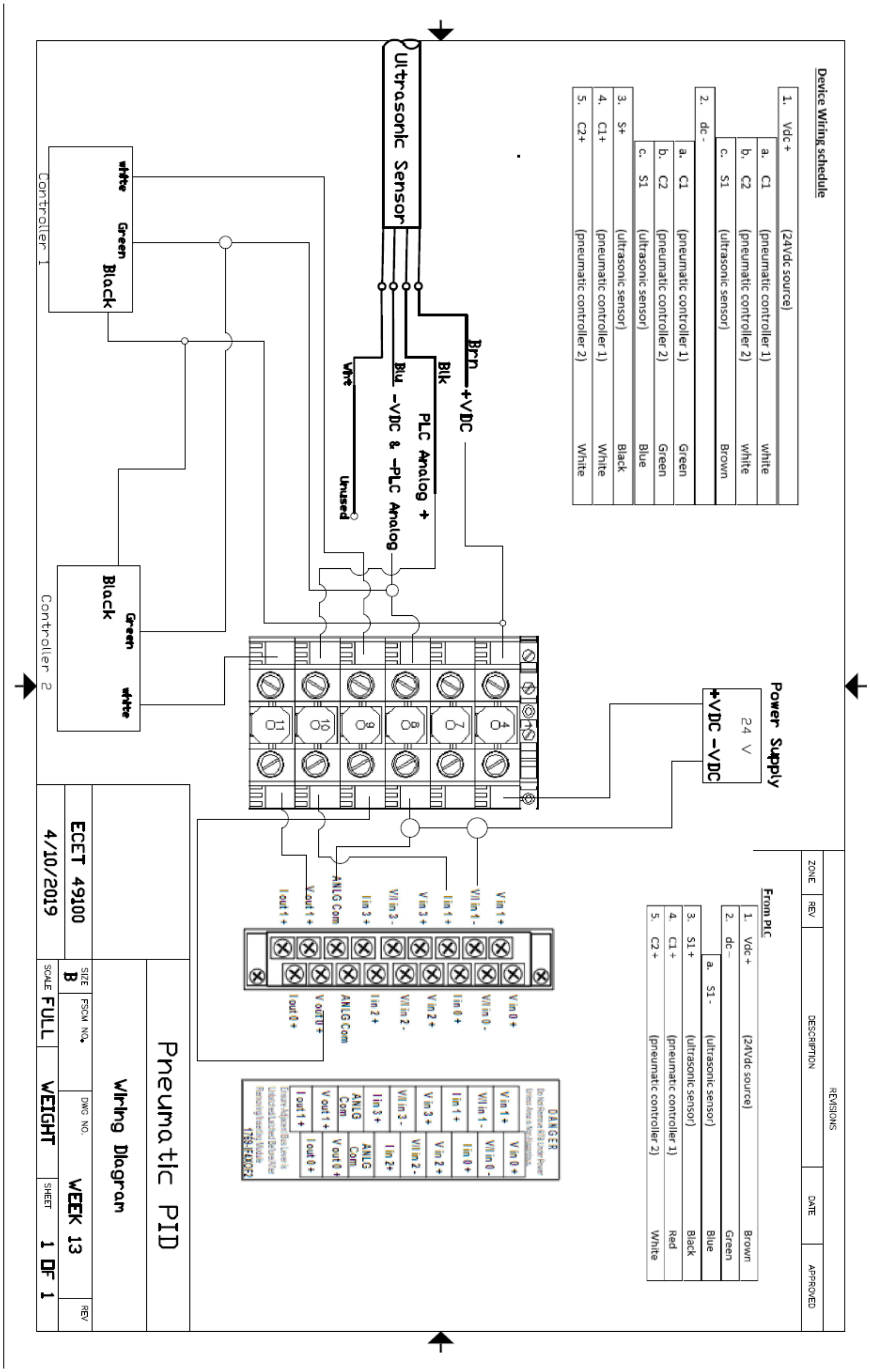


Figure 6 Wire Diagram

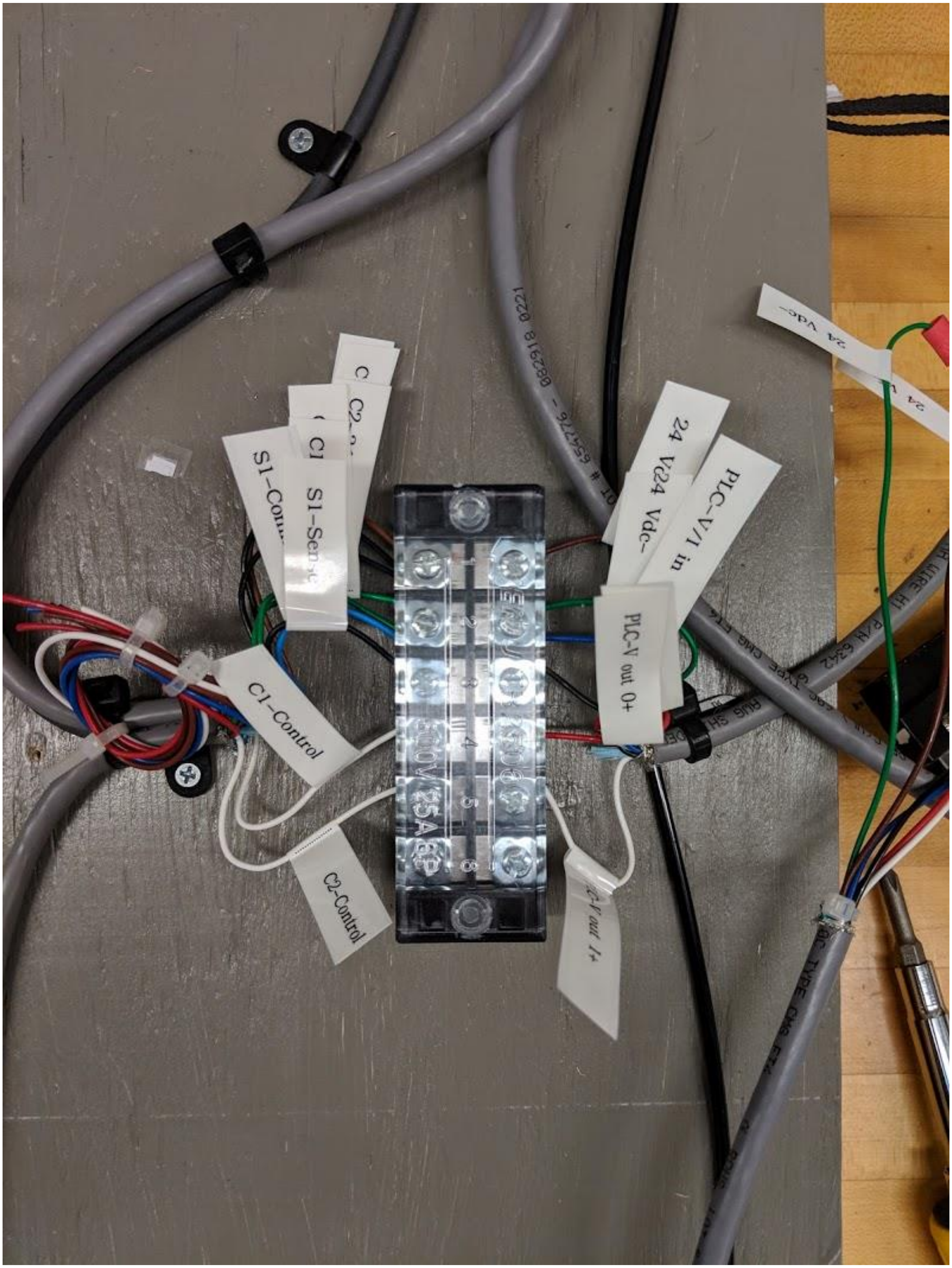


Figure 7 Wired Terminal Block

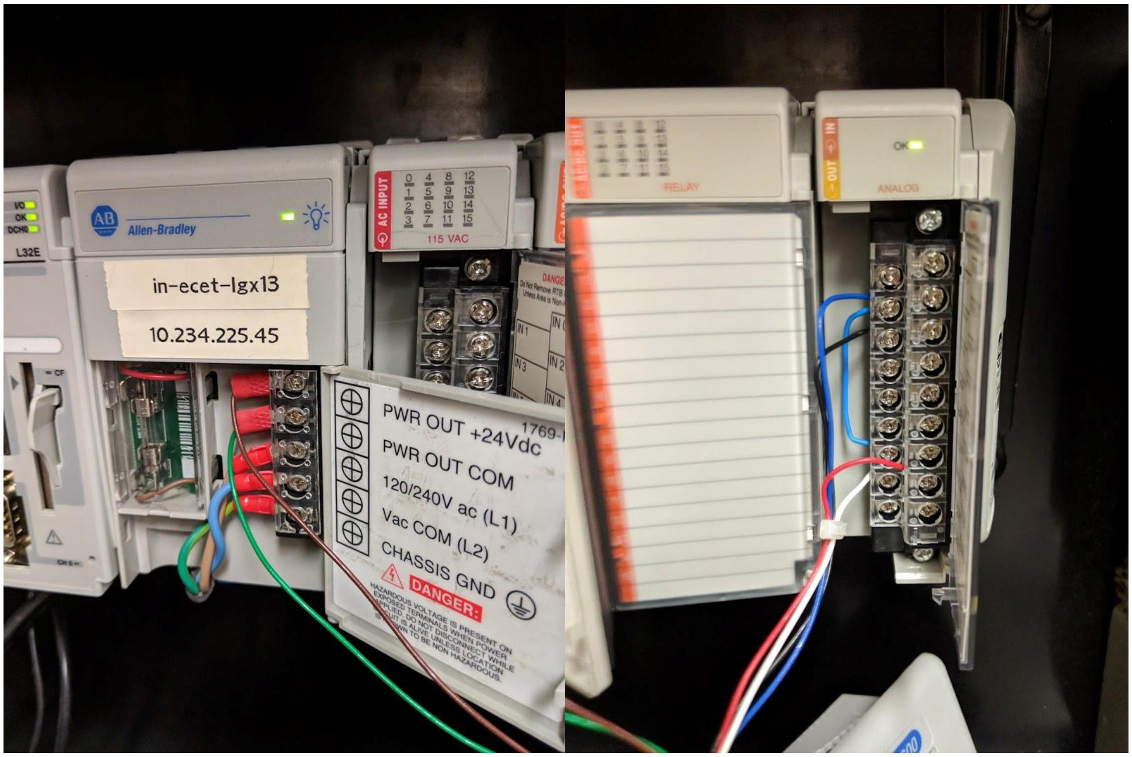


Figure 8 PLC Analog And Power Connections

Figure 9 Sensor Bracket Alignment

Wire Color	Device	Label
Black	Controller 1	C1-24 Vdc+
Green	Controller 1	C1-Common
White	Controller 1	C1- Control
Black	Controller 2	C2-24 Vdc+
Green	Controller 2	C2-Common
White	Controller 2	C2- Control
Brown	Sensor 1	S1-24 Vdc+
Blue	Sensor 1	S1-Common
Black	Sensor 1	S1- Sense
Brown	PLC	24 Vdc+
Green	PLC	23 Vdc-
Blue	PLC	PLC-V/I in-
Black	PLC	PLC-I in 1+
Red	PLC	PLC-V out 0+
White	PLC	PLC-V out 1+

Table 3 Wire Labels

Appendix D Troubleshooting Procedure

SAFETY PRECAUTIONS

3. Currents between 100 and 200 mA can be lethal. Follow appropriate electrical safety precautions.
4. Do not place objects between the cylinder pistons. Each cylinder is capable of approximately 44 ft·lbf.

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT

TOOLS

6. DC Power supply, 25v, dual output
7. Multimeter
8. Screw Driver, #2

NOTES: Full descriptions and Details can be viewed on the Full Bill of Materials.

PROCEDURE

6. **Preliminary**
    a. Place board on sturdy surface in a horizontal orientation with the cylinders towards you.
    b. Connect 100 PSI air supply to the system, with plug inserted in open tee ports.
        NOTE: If air hissing is observed search for and correct leaks.
    c. Disconnect PLC cable from the terminal
    d. Connect the first power supply channel to the system
        i. Positive to the first from the left on top of terminal strip
        ii. Neutral to the second from the left on top of terminal strip
    e. Turn the first power supply channel up to 24 Vdc, powering all devices
7. **Test Controller**
    a. Disconnect output hose and plug port
    b. Connect the second power supply positive to controller white wire.
    c. Connect the second power supply neutral to the controller
    d. Connect multimeter between the controller red wire and a neutral
    e. Turn the second power supply between 0-10 Vdc and observe that the multimeter follows the second power supply. The multimeter is reading the PSI output of the controller where 0-10 V is 0-100PSI.
        NOTE: If multimeter does not follow, contact Proportion Air for corrective steps.
    f. Reconnect controller in accordance with the build instructions.
8. **Test Sensor**
    a. Ensure power is applied by observing the lights on the back of the sensor are lit
    b. Connect multimeter between the sensor black wire and ground
    c. Observe that the current is at least 4 mA
    d. Pull cylinder piston out and observe current changing
        NOTE: If sensor does not act appropriately, replace sensor
9. **Test Cylinder**
    a. Pull out piston
    b. Plug port
    c. Release piston
    d. Observe piston does not retract too quickly
        NOTE: If cylinder does not act appropriately, replace cylinder

Appendix E Lab Instruction

Advanced Process Controls

ECET-499 Laboratory Assignment

(PLC/PID setup and observation)

Objectives:

The objective of this Lab is to familiarize the student with the capabilities of the RS Logix 5000 PID instruction, and to properly set up the pneumatic system to be controlled with this function using the PID tuning parameters to accomplish the best response to the external disturbance.

After successfully completing this lab, you should be able to:

- Use the PLC PID instruction properly
- Scale the inputs and outputs for the desired extension position of the pneumatic cylinder
- Properly acquire the desired position using the PID instruction
- Create a wave form display using the trend option in RS Logix 5000 software

Procedure:

Step 1

- Remove empty terminal block from PLC analog card, and install prewired terminal block and take note of each input and output assigned.
- Using the PLC power supply (24Vdc), install positive/negative source connections.
- Connect the pallets air supply port to a 100 PSI air supply source

Step 2

- Establish 2 analog outputs (0-10Vdc) and 1 analog input (4-20mA) in the program tags and verify they are sending and receiving properly
- Tip: ensure that the I/O are enabled accordingly for the Analog Card
- Locate the PID instruction and apply it to Rung 0, and name the program tag accordingly
    - assign the proper control variable and process variable program tags to the PID
- Open PID configuration menu and set ensure the following settings match below

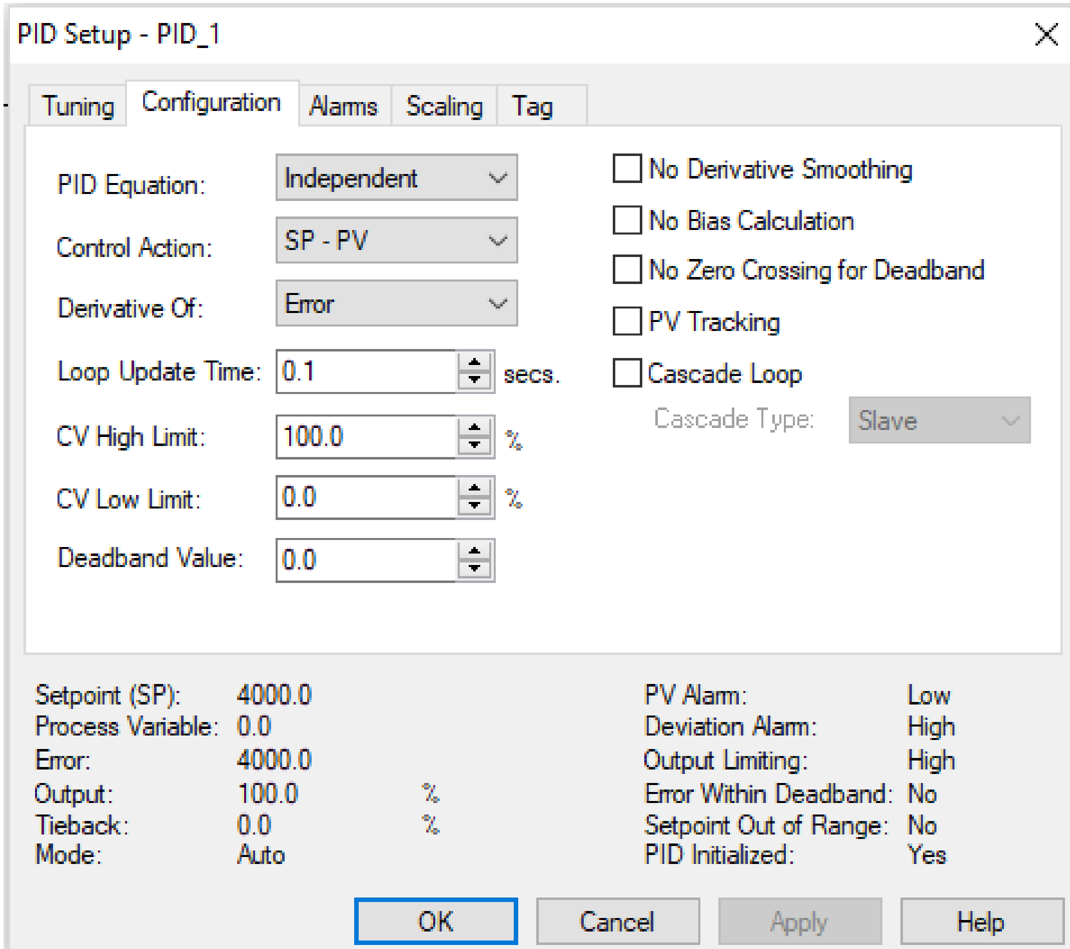


Figure 1

Step 3

- Using the Allen Bradley 1769-IF4XOF2 manual, locate the procedures to properly scale the PID process variable and control variable.
- Scale the inputs and outputs for the process variable (current) to 0-6000 bits representing the extension of the cylinder as 0 bits for 0 inches and 6000bits for 6 inches.
- Set the control variable min/max (Vdc)

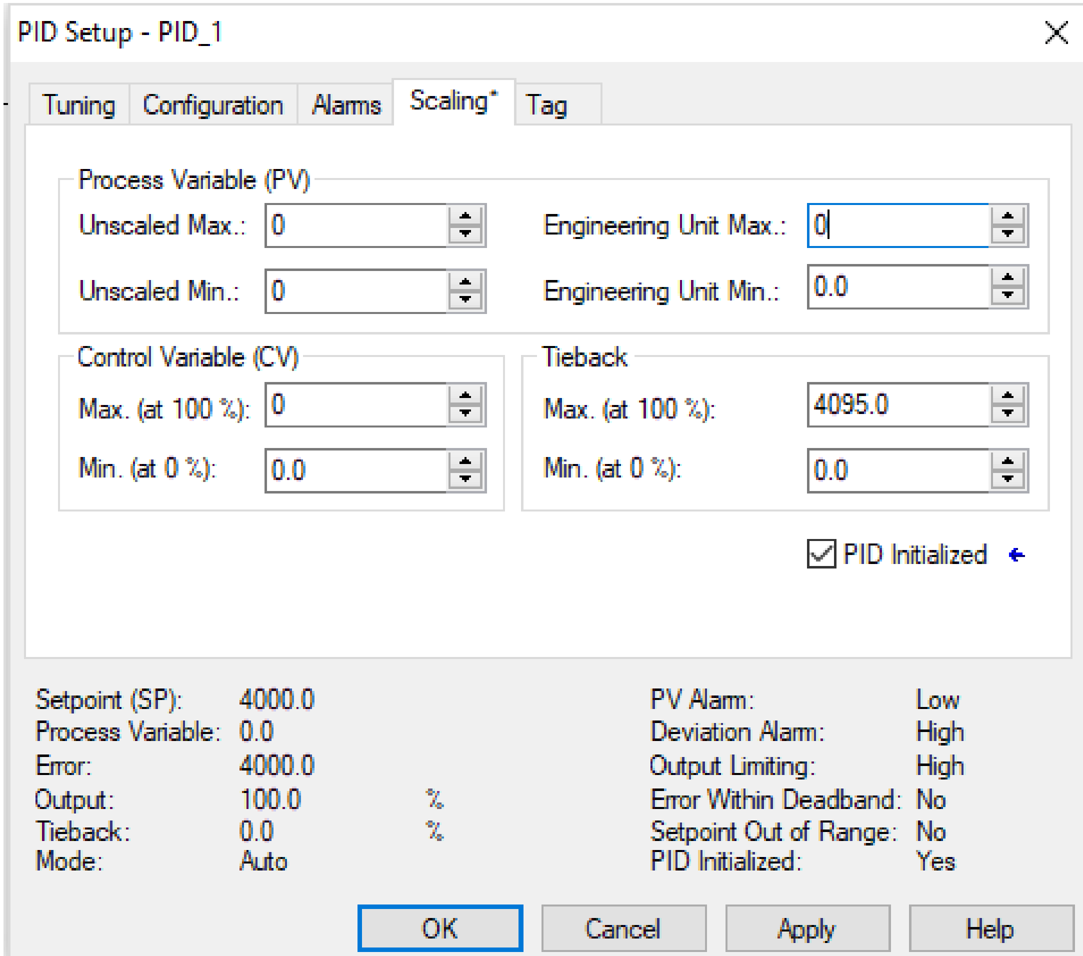


Figure 2

**Hint: PV-Unscaled min/max represents the minimum and maximum distance bit value from the ultrasonic sensor, Engineering min/max represents your desired scaled values.*

- Test your program to confirm the desired extension is achieved when setting the Set Point of the PID.

Step 4

- Apply a disturbance with the alternate cylinder and observe the response.

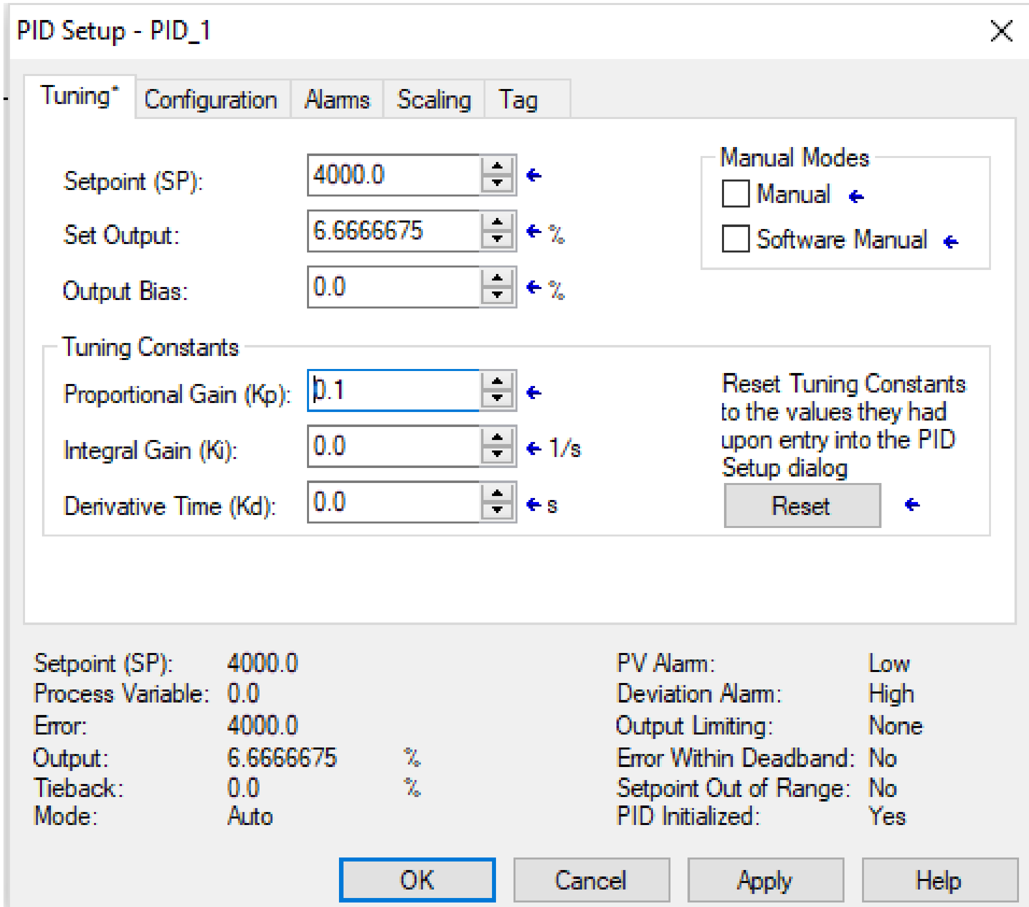
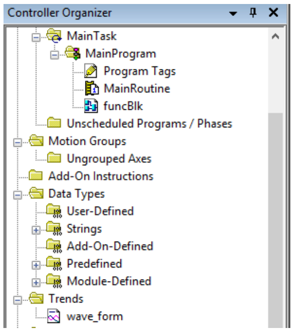


Figure 3

- Adjust the PID's tuning parameters to achieve the best response possible
  1. Adjust the Proportional (Kp) gain ONLY and observe response?
  2. Adjust the Integral (Ki) gain ONLY and observe response?
  3. Adjust the Derivative (Kd) gain ONLY and observe response?
  4. Adjust Kp, Ki gains ONLY and observe the BEST response?
  5. Adjust Kp, Ki, Kd gains and observe the BEST response

Step 5

- set up a wave form display using the trend function in RS logix software.



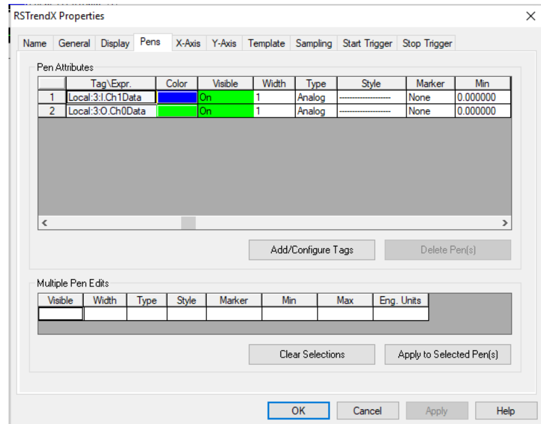


Figure 4

Figure 5

- Right click on Trends and create
- Go to “Pens” tab and assign inputs for Process Variable and Set Point.
- Open the display and run the Trend, observe the waveform response to variable disturbances to help visualize what is occurring inside of the PID.

Step 6

- Set up Controller 2 (disturbance) as an output, and program to provide a variable pattern of disturbances against the controlled cylinder, and adjust the PID tuning parameters accordingly in effort to maintain the most effective response.
- Examples of logic for disturbance are below:

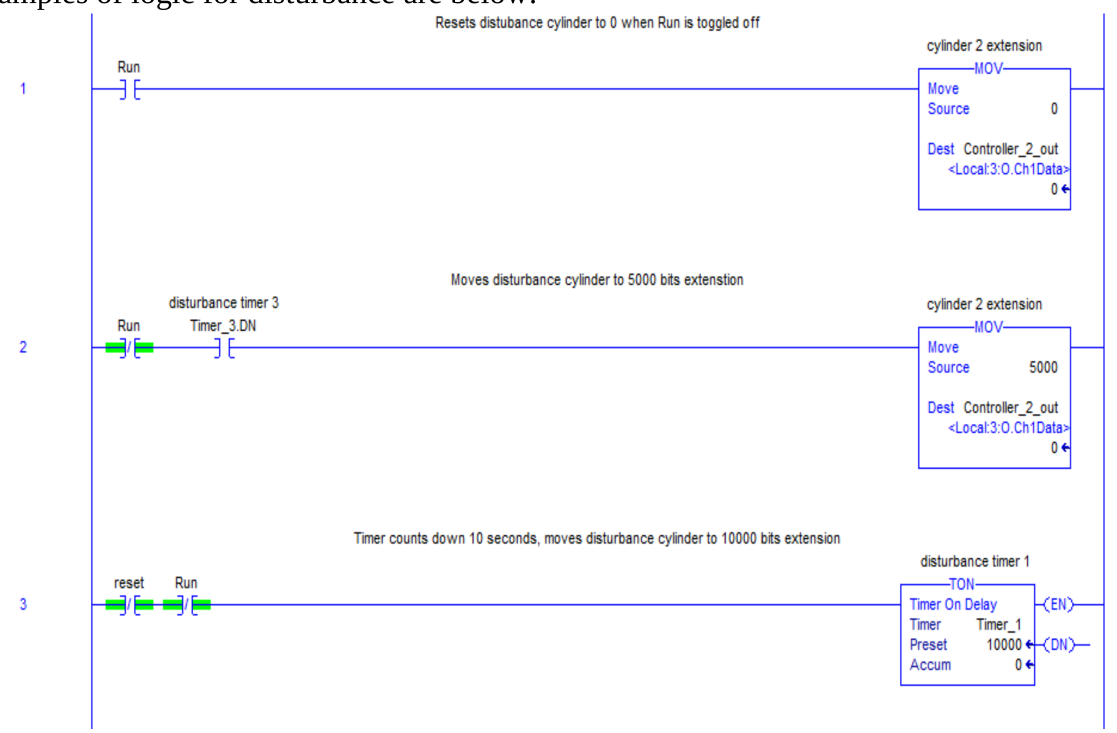


Figure 6

4
disturbance timer 1
Timer_1.DN
cylinder 2 extension
MOV
Move
Source 10000
Dest Controller_2_out
<Local:3:O.Ch1Data>
0
Timer counts down 10 seconds, moves disturbance cylinder to 15000 bits extension
5
disturbance timer 1
Timer_1.DN
disturbance timer 2
TON
Timer On Delay
Timer Timer_2
Preset 10000
Accum 0
EN
DN
6
disturbance timer 2
Timer_2.DN
cylinder 2 extension
MOV
Move
Source 15000
Dest Controller_2_out
<Local:3:O.Ch1Data>
0
7
disturbance timer 2
Timer_2.DN
disturbance timer 3
TON
Timer On Delay
Timer Timer_3
Preset 10000
Accum 0
EN
DN
Timer counts down 10 seconds, resets disturbance back to 5000 bits extension rung 2
8
disturbance timer 3
Timer_3.DN
reset
(End)

Figure 7

Product data sheet
Characteristics

VM1CAQ
ultrasonic sensor flat form + M18 - Sn508mm - 4..20mA - M12

Product availability : Non-Stock - Not normally stocked in distribution facility

Price* : 142.00 USD

Main

Range of product	Hyde Park
Sensor type	Ultrasonic sensor
Series name	Virtu VM1
Device short name	VM1
Sensor design	Flat form + cylindrical M18
[Sn] nominal sensing distance	20 in (508 mm)
Type of sensing window	Adjustable
Material	Plastic
Enclosure material	Valox
Front material	Glass epoxy
Type of output signal	Analog
ISO thread	M18 x 1
Wiring technique	4-wire
[Us] rated supply voltage	15...24 V DC (overload and short-circuit protection)
Supply voltage limits	13...28 V DC
Analogue output range	4...20 mA autoslope
Electrical connection	1 male connector M12 4 pins
Product specific application	-

Complementary

[Sd] sensing range	2...20 in (50.8...508 mm)
[Sa] assured operating distance	2...20 in (50.8...508 mm) with remote teach push-button
Blind zone	0...2.01 in (0...51 mm)
Transmission frequency	300 kHz
Repeat accuracy	1.27 %
Beam angle	5 °
Minimum size of detected object	Cylinder diameter 2.5 mm - up to 200 mm sensing distance
Status LED	1 LED - green - off when object is within range
Current consumption	40 mA
Maximum switching current	40 mA (reverse polarity protection)

Resistance to electrostatic discharge	8 kV (level 4) conforming to IEC 61000-4-2
Height	1.72 in (43.7 mm)
Width	0.71 in (18 mm)
Depth	1.72 in (43.7 mm)
Length	2.58 in (65.61 mm)
Product weight	0.07 lb(US) (0.033 kg)

Environment

Product certifications	UL
Marking	CE
NEMA degree of protection	NEMA 4X (indoor use only)
IP degree of protection	IP67
Ambient air temperature for operation	-22...158 °F (-30...70 °C)
Ambient air temperature for storage	-40...185 °F (-40...85 °C)
Relative humidity	100 % without condensation
Vibration resistance	+/-1 mm conforming to IEC 60068-2-6 10...55 Hz
Shock resistance	30 gn in all 3 axes 11 ms conforming to IEC 60068-2-27
Resistance to electromagnetic fields	9.14 V/yd (10 V/m) (level 3) conforming to IEC 61000-4-3
Resistance to fast transients	1 kV (level 3) conforming to IEC 61000-4-4

Ordering and shipping details

Category	22490 - SENSORS-ULTRASONIC (XX5,6)
Discount Schedule	DS2
GTIN	00785901596585
Nbr. of units in pkg.	1
Package weight(Lbs)	0.12
Returnability	N
Country of origin	US

Offer Sustainability

RoHS (date code: YYWW)	Compliant - since 1150 - Schneider Electric declaration of conformity Schneider Electric declaration of conformity
REACh	Reference contains SVHC above the threshold - Go to CaP for more details Go to CaP for more details
Product end of life instructions	Available
California proposition 65	WARNING: This product can expose you to chemicals including:
- - - - - - - Substance 1	Diisononyl phthalate (DINP), which is known to the State of California to cause cancer, and
- - - - - - - Substance 2	Di-isodecyl phthalate (DIDP), which is known to the State of California to cause birth defects or other reproductive harm.
- - - - - - - More information	For more information go to www.p65warnings.ca.gov

Contractual warranty

Warranty period	18 months

NOTE: After the teach button is released, alternating green and amber LEDs indicate that target was not detected, or the teaching procedure timed out. Repeat the “Teaching the Sensor Window” procedure.

REMARQUE : Après avoir relâché le bouton d’apprentissage, les voyants LED vert et orange s’allumant alternativement indiquent que l’objet n’a pas été détecté ou que le délai d’attente de la procédure d’apprentissage a pris fin. Répétez la procédure d’apprentissage de la zone du détecteur.

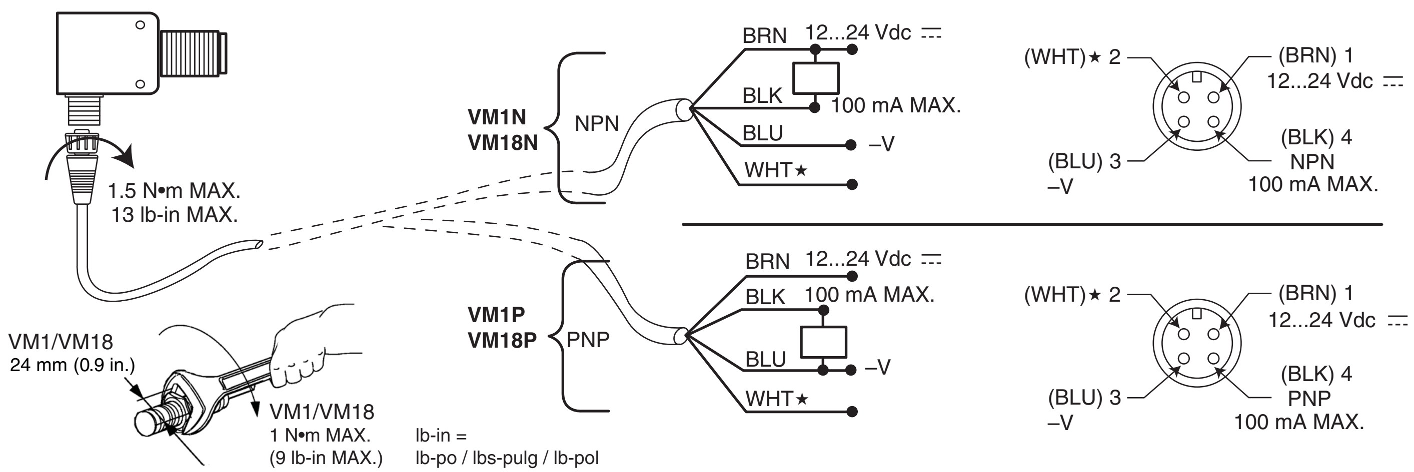
HINWEIS: Wenn nach Freigabe der Teach-Taste die LED abwechselnd grün und orange leuchten, wurde entweder keine Grenze erkannt oder die Zeit für das Teach-Verfahren wurde überschritten. In diesem Fall muss das Teach-Verfahren für das Einstellen des Schaltbereichs wiederholt werden.

NOTA: Una vez que suelta el botón de aprendizaje, si se alternan los LED verde y ámbar esto indica que el objeto no fue detectado, o bien, que el tiempo del procedimiento de aprendizaje expiró. Repita el procedimiento “Aprendizaje de la zona de detección”.

NOTA: Dopo aver rilasciato il pulsante di apprendimento, i LED alternati verde e ambra indicano che l’oggetto non è stato rilevato o che il tempo della procedura di apprendimento è scaduto. Ripetere la procedura “Apprendimento della finestra di rilevamento”.

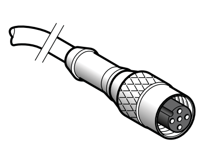
NOTA: Depois que o botão de ensino for solto, a alternância dos LEDs verde e âmbar indica que o alvo não foi detectado ou que o procedimento de aprendizagem expirou. Repita o procedimento “Aprendizagem da Janela do Sensor”.

Wiring / Câblage / Kabel / Cableado / Cablaggio / Cablagem

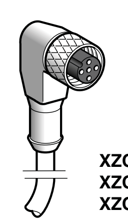


BRN	Brown, +V	Brun, +V	Braun, +V	Marrón, +V	Marrone, +V	Castanho, +V
BLK	Black, Ouput	Noir, Sortie	Schwarz, Ausgang	Negro, Salida	Nero, Uscita	Preto, Saída
WHT ★	White, Teach Input	Blanc, Entrée d’apprentissage	Weiß, Teach-Eingang	Blanco, Entrada de aprendizaje	Bianco, Ingresso Apprendimento	Branco, Entrada Aprendizagem
BLU	Blue, –V	Bleu, –V	Blau –V	Azul, –V	Blu, –V	Azul, –V
NPN	Sinking	Commutation sur la charge du potentiel **négatif**	Stromziehend	Conmutación en la carga de potencial negativo	Assorbimento	Lógica negativa
PNP	Sourcing	Commutation sur la charge du potentiel **positif**	Stromliefernd	Conmutación en la carga de potencial positivo	Emissione	Lógica positiva
★	Used only during teach mode. No connection during normal operation.	Utilisé seulement durant le mode d’apprentissage. Aucun raccordement en fonctionnement normal.	Wird nur im Teach-Modus verwendet. Ist bei normalem Betrieb nicht angeschlossen.	Utilizar sólo durante el modo de aprendizaje. No hay conexión durante el modo de funcionamiento normal.	Usato soltanto durante la modalità di apprendimento. Nessun collegamento durante il funzionamento normale.	Usado somente durante o modo de aprendizagem. Nenhuma ligação durante funcionamento normal.

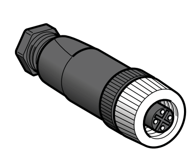
Cabling Accessories / Accessoires de câblage / Anschlusszubehör / Accesorios de cableado / Accessori di cablaggio / Acessórios de cablagem



XZCP1141L2 (2 m / 6.6 ft)
XZCP1141L5 (5 m / 16.4 ft)
XZCP1141L10 (10 m / 32.8 ft)



XZCP1241L2 (2 m / 6.6 ft)
XZCP1241L5 (5 m / 16.4 ft)
XZCP1241L10 (10 m / 32.8 ft)



XZCC12FDM40B
XZCC12FDP40B

XZCC12FCM40B
XZCC12FCP40B

ft = pi / ft / pies / piedi / pés

VM1••• / VM18••• www.schneider-electric.com

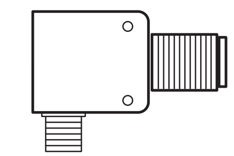
VM1NNO•••, VM18NNO•••
NO / NPN output; Sortie NPN / NO; Schliesser / NPN-Ausgang; Salida NO / NPN; Uscita NO / NPN; Saída NO / NPN

VM1PNO•••, VM18PNO•••
NO / PNP output; Sortie PNP / NO; Schliesser / PNP-Ausgang; Salida NO / PNP; Uscita NO / PNP; Saída NO / PNP

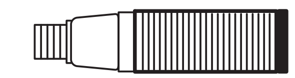
VM1NNC•••, VM18NNC•••
NC / NPN output; Sortie NPN / NC; Öffner / NPN-Ausgang; Salida NC / NPN; Uscita NC / NPN; Saída NC / NPN

VM1PNC•••, VM18PNC•••
NC / PNP output; Sortie PNP / NC; Öffner / PNP-Ausgang; Salida NC / PNP; Uscita NC / PNP; Saída NC / PNP

VM1●●●



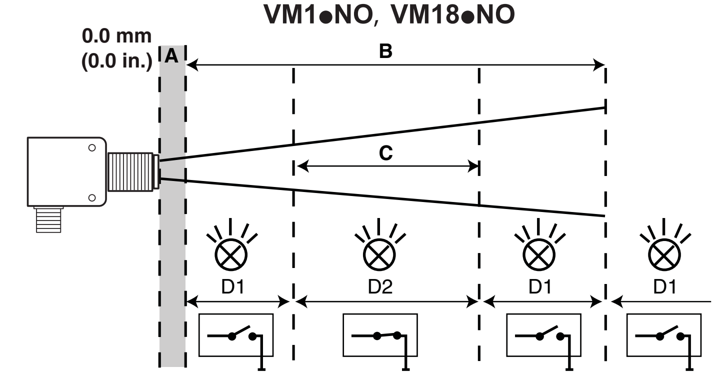
VM18●●●



Operation / Fonctionnement / Betrieb / Funcionamiento / Funzionamento / Operação

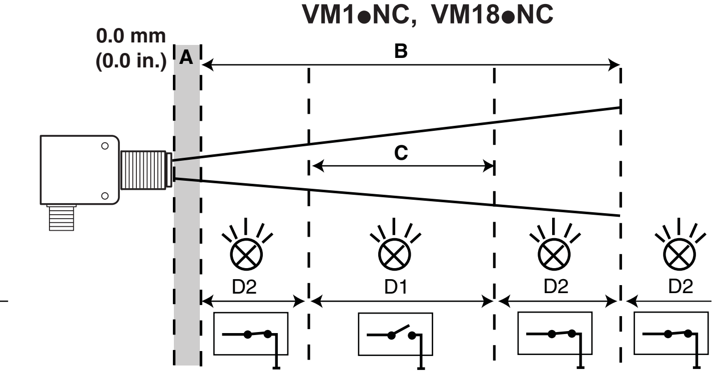
NO

VM1●NO, VM18●NO



NC

VM1●NC, VM18●NC



	A	B
VM1/VM18	50.8 mm (2 in.)	500 mm (20 in.)

in. = po / in. / pulg / pollici / pol

A	Deadband erratic operation within this range	Zone aveugle, fonctionnement aléatoire dans cette plage	Totzone: Fehlerhafter Betrieb innerhalb dieses Bereichs	Zona muerta: funcionamiento aleatorio dentro de esta zona	Zona morta: Funzionamento errato all’interno di questo campo	Zona cega: operação errática dentro desta faixa
B	Sensing range	Domaine de détection possible	Erfassungsbereich	Zona de detección	Campo di rilevamento	Gama de detecção
C	Sensing window	Zone active de détection (après apprentissage)	Schaltbereich	Zona activa de detección	Finestra di rilevamento	Janela de actuação do sensor
D	Green and amber LEDs	Voyants LED vert et orange	Grüne und orange LED	LED verde y ámbar	LED verde e ambra	LEDs verde e âmbar
D1	Green LED is on, amber LED is off	Voyant LED vert est allumé, voyant LED orange est éteint	Grüne LED leuchtet, orange LED erlischt	LED verde está encendido, LED ámbar está apagado	Il LED verde è acceso, il LED ambra è spento	O LED verde está aceso, o LED âmbar está desligado
D2	Green LED is off, amber LED is on	Voyant LED vert est éteint, voyant LED orange est allumé	Grüne LED erlischt, orange LED leuchtet	LED verde está apagado, LED ámbar está encendido	Il LED verde è spento, il LED ambra è acceso	O LED verde está desligado, o LED âmbar está aceso
NO	Normally open output	Sortie normalement ouverte	Ausgang ist ein Schließer	Salida normalmente abierta	Uscita normalmente aperta	Saída nor aberta
NC	Normally closed output	Sortie normalement fermée	Ausgang ist ein Öffner	Salida normalmente cerrada	Uscita normalmente chiusa	Saída nor fechada

⚠ WARNING / AVERTISSEMENT / WARNUNG / ADVERTENCIA / AVVERTENZA / ADVERTÊNCIA

UNINTENDED OPERATION

Do not use this product to detect objects within the deadband or outside the sensing range.

Failure to follow these instructions can result in death, serious injury, or equipment damage.

FONCTIONNEMENT ALÉATOIRE

N'utilisez pas ce produit pour détecter des objets dans la zone aveugle ou en dehors du domaine de détection possible.

Le non-respect de cette instruction peut entraîner des blessures graves ou mortelles ou des dommages à l'équipement.

UNSACHGEMÄSSE INBETRIEBNAHME

Dieses Produkt darf nicht für die Erfassung von Objekten innerhalb der Totzone oder außerhalb des Erfassungsbereichs verwendet werden.

Bei Nichtbeachtung dieser Anweisung besteht die Gefahr von schweren oder tödlichen Verletzungen und Geräteschäden.

FUNCIONAMIENTO ACCIDENTAL

No emplee este producto para detectar objetos dentro de la zona muerta o fuera de la zona de detección.

El incumplimiento de esta instrucción puede causar la muerte, lesiones graves o daño al equipo.

FUNZIONAMENTO INCONTROLLATO

Non usare questo prodotto per il rilevamento di oggetti all'interno della zona morta o all'esterno dell campo di rilevamento.

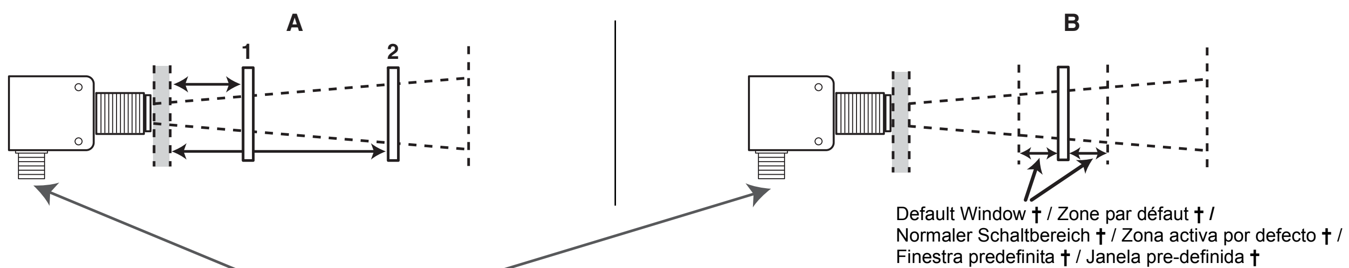
L'inosservanza di queste istruzioni può provocare la morte, lesioni gravi o danni al macchinario.

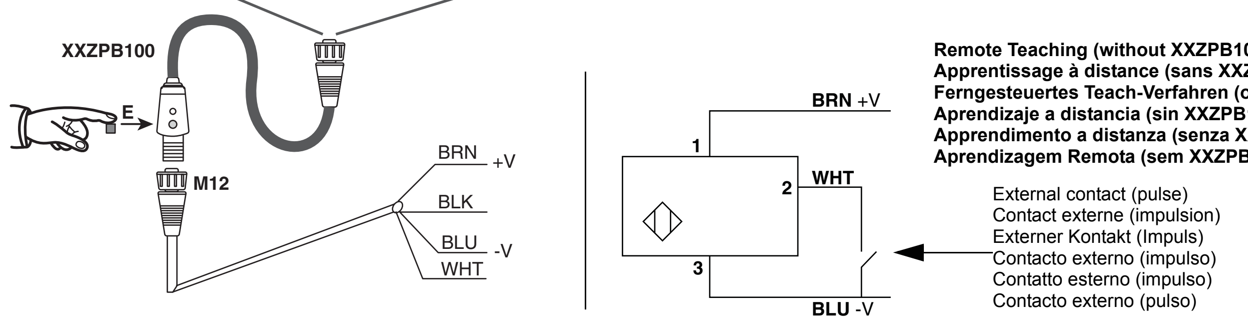
FUNCIONAMENTO INVOLUNTÁRIO

Não use este produto para detectar objectos dentro da zona cega ou fora da gama de detecção do sensor.

A operação involuntária pode resultar em morte, ferimentos graves ou danos no equipamento.

Teaching the Sensing Window Using Accessory XXZPB100 / Apprentissage de la zone active de détection à l'aide de l'accessoire XXZPB100 / Teach-Verfahren für den Schaltbereich unter Verwendung des Zubehörs XXZPB100 / Aprendizaje de la zona activa de detección empleando el accesorio XXZPB100 / Apprendimento della finestra di rilevamento mediante l'accessorio XXZPB100 / Aprendizagem da Janela de Actuação do Sensor usando o Acessório XXZPB100





Remote Teaching (without XXZPB100)
Apprentissage à distance (sans XXZPB100)
Ferngesteuertes Teach-Verfahren (ohne XXZPB100)
Aprendizaje a distancia (sin XXZPB100)
Apprendimento a distanza (senza XXZPB100)
Aprendizagem Remota (sem XXZPB100)

† Default Window: The default teach window is normally 12.7 mm (0.5 in.) in front of and behind the target distance. The default teach window may vary by reference (catalog number).

NOTE: For remote teaching without the XXZPB100, connect an external contact between the WHT and BLU wires.

1 Install teach accessory XXZPB100.

2 Press and hold the teach button (E). The green LED is off and the amber LED fast flashes. Continue holding the teach button until the green LED slow flashes and the amber LED turns off (3s).

† Zone par défaut: La zone d'apprentissage par défaut est normalement à 12,7 mm (0,5 po) en avant ou en arrière de la distance de l'objet. La zone par défaut peut varier selon la référence (numéro de catalogue).

REMARQUE : Pour l'apprentissage à distance sans l'accessoire XXZPB100, raccordez un contact externe entre les fils blanc (WHT) et bleu (BLU).

1 Installez l'accessoire d'apprentissage XXZPB100.

2 Appuyez sur le bouton d'apprentissage (E) et maintenez-le enfoncé. Le voyant LED vert est éteint et le voyant LED orange clignote rapidement. Continuez à tenir le bouton enfoncé jusqu'à ce que le voyant LED vert clignote lentement et que le voyant LED orange s'éteigne (3 s.).

† Normaler Schaltbereich: Der normale Schaltbereich liegt generell 12,7 mm vor und hinter der gewünschten Zielgrenze. Der normale Schaltbereich kann je nach Bezug (Katalognummer) unterschiedlich sein.

HINWEIS: Für das ferngesteuerte Teach-Verfahren ohne XXZPB100 muss zwischen dem weißen (WHT) und blauen (BLU) Draht ein externer Kontakt angeschlossen werden.

1 Teach-Zubehör XXZPB100 installieren.

2 Den Teach-Schalter (E) gedrückt halten. Der grüne LED erlischt und der orange LED blinkt schnell. Den Teach-Schalter weiterhin gedrückt halten, bis der grüne LED langsam blinkt und der orange LED erlischt (3 s).

† Zona por defecto: La zona de aprendizaje por defecto es normalmente de 12,7 mm (0,5 pulg) al frente y atrás de la distancia del objeto. La zona de aprendizaje por defecto puede variar por referencia (número de catálogo).

NOTA: Para el aprendizaje a distancia sin el accesorio XXZPB100, conecte un contacto externo entre los cables WHT y BLU.

1 Instale el accesorio de aprendizaje XXZPB100.

2 Oprima y mantenga oprimido el botón de aprendizaje (E). El LED verde se apaga y el LED ámbar parpadea rápidamente. Continúe oprimiendo el botón de aprendizaje hasta que el LED verde parpadee lentamente y el LED ámbar se apague (3 s).

† Finestra predefinita : La finestra predefinita è normalmente di 12,7 mm (0,5 pollici) rispetto alla distanza dell'oggetto sia di fronte che di dietro. La finestra predefinita può variare secondo il riferimento (numero di cat.).

NOTA: Per l'apprendimento a distanza senza XXZPB100, collegare un contatto esterno tra i cavi WHT e BLU.

1 Installare l'accessorio di apprendimento XXZPB100.

2 Premere e tenere premuto il pulsante di apprendimento (E). Il LED verde si spegne e il LED ambra lampeggia rapidamente. Tenere premuto il pulsante di apprendimento finché il LED verde lampeggia lentamente e il LED ambra si spegne (3s).

† Janela pre-definida: A janela pre-definida de aprendizagem está normalmente 12,7 mm (0,5 pol.) na frente e atrás da distância do alvo. A janela pre-definida pode variar pela referência (número do catálogo).

NOTA: Para aprendizagem remota sem o XXZPB100, ligue um contacto externo entre os fios WHT e BLU.

1 Instale o acessório de aprendizagem XXZPB100.

2 Prima e mantenha premido o botão de ensino (E). O LED verde está desligado e o LED âmbar pisca rápidamente. Continue premindo o botão de ensino até que o LED verde pisque lentamente e o LED âmbar entre em repouso (3s).

3 Release the teach button. The green LED continues to slow flash green: the sensor is requesting the first limit.

4 Continue with procedure A or B, depending on the type window desired.

A. **Standard Teach Window.** This procedure teaches a window between two target distances. The window limits can be taught in either order.

1 Within 30 s, place a target at position 1 or 2, then press and release the teach button. The green LED turns off and the amber LED slow flashes: the sensor is requesting the second limit.

2 Within 30 s, place a target at the other position (1 or 2), then press and release the teach button. The green LED fast flashes for 3 s indicating that the window limits were successfully saved. The sensor now operates with the new window limits.

3 Remove the teach accessory.

B. **Default Teach Window.** This procedure teaches a default window. †

1 Within 30 s, place a target at the center of the desired window.

2 Press and release the teach button twice within 1 s. The green LED fast flashes for 3 s indicating that the window limits were successfully saved. The sensor now operates with this new window. If the window is not present, repeat the teaching procedure. Ensure that the time between the two presses of the teach button does not exceed 1 s.

3 Remove the teach accessory.

Continued

3 Relâchez le bouton d'apprentissage. Le voyant LED vert continue à clignoter lentement : le détecteur demande la première limite.

4 Continuez avec la procédure A ou B, selon le type de zone désiré.

A. **Zone d'apprentissage standard.** Cette procédure enregistre les distances entre deux objets dans la zone. Les limites de la zone peuvent être enregistrées dans n'importe quel ordre.

1 Dans les 30 s., placez un objet à l'emplacement 1 ou 2, puis appuyez sur le bouton d'apprentissage et relâchez-le. Le voyant LED vert s'éteint et le voyant LED orange clignote lentement : le détecteur demande la deuxième limite.

2 Dans les 30 s., placez un objet à l'autre emplacement (1 ou 2), puis appuyez sur le bouton d'apprentissage et relâchez-le. Le voyant LED vert clignote rapidement pendant 3 s., indiquant que les limites de la zone ont été enregistrées avec succès. Le détecteur fonctionne maintenant avec les nouvelles limites de la zone.

3 Retirez l'accessoire d'apprentissage.

B. **Zone d'apprentissage par défaut.** Cette procédure enregistre une zone par défaut. †

1 Dans les 30 s., placez un objet au centre de la zone désirée.

2 Appuyez sur le bouton d'apprentissage et relâchez-le deux fois au bout de 1 s. Le voyant LED vert clignote rapidement pendant 3 s. indiquant que les limites de la zone ont été enregistrées avec succès. Le détecteur fonctionne maintenant avec cette nouvelle zone. Si la zone n'est pas présente, répétez la procédure d'apprentissage. Assurez-vous que l'intervalle entre les deux fois que vous appuyez sur le bouton d'apprentissage ne dépasse pas 1 s.

3 Retirez l'accessoire d'apprentissage.

Suite

3 Die Teach-Taste loslassen. Der grüne LED blinkt weiterhin langsam, was darauf hinweist, dass der Sensor auf die Eingabe der ersten Grenze wartet.

4 Je nach Art des gewünschten Schaltbereichs das Verfahren A oder B durchführen.

A. **Normaler Teach-Schaltbereich.** Mithilfe dieses Verfahrens wird ein Schaltbereich zwischen zwei Grenzen eingestellt. Die Schaltbereichsgrenzen können in beliebiger Reihenfolge durch die Teach-Funktion „trainiert" werden.

1 Innerhalb von 30 s ein Objekt an Position 1 oder 2 einführen und kurz den Teach-Schalter drücken. Der grüne LED erlischt und der orange LED blinkt langsam, was darauf hinweist, dass der Sensor auf die Eingabe der zweiten Grenze wartet.

2 Innerhalb von 30 s ein Objekt an der anderen Position (1 oder 2) einführen und kurz den Teach-Schalter drücken. Der grüne LED blinkt 3 s lang schnell, um anzuzeigen, dass die Grenzen erfolgreich gespeichert wurden. Der Sensor wirkt nun in diesem neuen Schaltbereich.

3 Das Teach-Zubehör entfernen.

B. **Normaler Teach-Schaltbereich.** Mithilfe dieses Teach-Verfahrens wird ein normaler Schalterbereich eingestellt. †

1 Innerhalb von 30 s ein Objekt in die Mitte des gewünschten Schaltbereichs einführen.

2 Die Teach-Taste innerhalb von 1 s zweimal kurz drücken. Der grüne LED blinkt 3 s lang schnell, um anzuzeigen, dass die Grenzen erfolgreich gespeichert wurden. Der Sensor wirkt nun in diesem neuen Schaltbereich. Falls der Schaltbereich nicht vorhanden ist, muss das oben beschriebene Teach-Verfahren wiederholt werden. Es ist sehr wichtig, dass zwischen jedem Drücken der Teach-Taste nicht mehr als 1 Sekunde vergeht.

3 Das Teach-Zubehör entfernen.

Forts.

3 Suelte el botón de aprendizaje. El LED verde continúa parpadeando lentamente: el sensor está solicitando el primer límite.

4 Continúe con el procedimiento A o B, según el tipo de zona deseado.

A. **Zona de aprendizaje normal.** Este procedimiento enseña las distancias entre dos objetos en la zona. Los límites de la zona pueden enseñarse en cualquier orden.

1 Dentro de 30 segundos, coloque un objeto en la posición 1 ó 2, luego oprima y suelte el botón de aprendizaje. El LED verde se apaga y el LED ámbar parpadea lentamente: el sensor está solicitando el segundo límite.

2 Dentro de 30 segundos, coloque un objeto en la otra posición (1 ó 2), luego oprima y suelte el botón de aprendizaje. El LED verde parpadea rápidamente durante 3 segundos, lo cual indica que los límites de la zona se guardaron exitosamente. Ahora, el sensor funciona con los nuevos límites de la zona.

3 Retire el accesorio de aprendizaje.

B. **Zona de aprendizaje por defecto.** Este procedimiento enseña una zona por defecto. †

1 Dentro de 30 segundos, coloque un objeto en el punto intermedio de la zona deseada.

2 Oprima y suelte el botón de aprendizaje dos veces dentro de 1 segundo. El LED verde parpadea rápidamente durante 3 segundos, lo cual indica que los límites de la zona se guardaron exitosamente. Ahora, el sensor funciona con esta nueva zona. Si la zona no está disponible, repita el procedimiento de aprendizaje. Asegúrese de que el tiempo entre las dos veces que oprime el botón de aprendizaje no exceda 1 segundo.

3 Retire el accesorio de aprendizaje.

Continuación

3 Rilasciare il pulsante di apprendimento. Il LED verde continua a lampeggiare lentamente verde: il sensore richiede il primo limite.

4 Continuare con la procedura A o B, secondo il tipo di finestra desiderato.

A. **Finestra di apprendimento standard.** Questa procedura prevede una finestra tra due distanze dell'obiettivo. I limiti della finestra possono essere previsti in entrambi gli ordini.

1 Entro 30 s, collocare un oggetto in posizione 1 o 2, poi premere e rilasciare il pulsante di apprendimento. Il LED verde si spegne e il LED ambra lampeggia lentamente: il sensore richiede il secondo limite.

2 Entro 30 s, collocare un oggetto nell'altra posizione (1 o 2), poi premere e rilasciare il pulsante di apprendimento. Il LED verde lampeggia rapidamente per 3 s, ad indicare che i limiti della finestra sono stati memorizzati. Ora il sensore funziona con i limiti della nuova finestra.

3 Rimuovere l'accessorio di apprendimento.

B. **Finestra di apprendimento predefinita.** Questa procedura prevede una finestra predefinita. †

1 Entro 30 s, collocare un oggetto al centro della finestra desiderata.

2 Premere e rilasciare due volte il pulsante di apprendimento entro 1 s. Il LED verde lampeggia rapidamente per 3 s , ad indicare che i limiti della finestra sono stati memorizzati. Ora il sensore funziona con la nuova finestra. Se la finestra non è presente, ripetere la procedura di apprendimento. Assicurarsi che il tempo intercorrente tra le due pressioni del pulsante di apprendimento non superi 1 s.

3 Rimuovere l'accessorio di apprendimento.

Continuazione

3 Solte o botão de ensino. O LED verde continua a piscar lentamente. O sensor está solicitando o primeiro limite.

4 Continue o procedimento A ou B, dependendo do tipo de janela desejado.

A. **Janela de detecção programável.** Este procedimento aprende uma janela entre duas distâncias do alvo. Os limites desta janela podem ser aprendidos em qualquer ordem.

1 Dentro de 30 s, coloque um alvo na posição 1 ou 2, em seguida prima e solte o botão de ensino. O LED verde entra em repouso e o LED âmbar pisca lentamente. O sensor está solicitando o segundo limite.

2 Dentro de 30 s, coloque um alvo na outra posição (1 ou 2), em seguida prima e solte o botão de ensino. O LED verde pisca rapidamente durante 3s, indicando que os limites da janela foram gravados com êxito. O sensor agora opera com os novos limites da janela.

3 Retire o acessório de aprendizagem.

B. **Janela de detecção pre-definida.** Este procedimento aprende uma janela pre-definida.†

1 Dentro de 30 s, coloque um alvo no centro da janela desejada.

2 Prima e solte duas vezes o botão de ensino dentro de 1 s. O LED verde pisca rapidamente durante 3 s indicando que os limites da janela foram gravados com êxito. O sensor agora opera com esta nova janela. Se a janela não estiver presente, repita o procedimento de aprendizagem. Assegure-se de que o tempo entre as duas premidas do botão de ensino não excedam 1 s.

3 Retire o acessório de aprendizagem.

Continuação

QB1X & QB2X

PROPORTION-AIR
Electro-Pneumatic Pressure Regulators & Flow Controllers

INSTALLATION & MAINTENANCE INSTRUCTIONS

DESCRIPTION / IDENTIFICATION

The QBX series valve uses Proportion-Air closed loop technology for Pressure control. It gives an output pressure proportional to an electrical command signal input.

The QB1X is a complete closed loop system consisting of valves, manifold, housing and electronic controls. Pressure is controlled by the use of two solenoid valves. One valve functions as inlet control, the other as exhaust. The pressure output is measured by a pressure transducer internal to the QB1X and provides a feedback signal to the electronic controls. This feedback signal is compared with the command signal input. A difference between the two signals causes one of the solenoid valves to open, allowing flow in or out of the system. Accurate pressure is maintained by controlling these two valves.

The QB2X is similar to the QB1X but uses a double loop control scheme. In addition to the internal pressure transducer, the QB2X receives an electrical signal from an external sensing device. This primary feedback signal is compared against the command signal input. This comparison is then summed with the internal pressure transducer signal. The gain of the circuit is such that priority is given to the external feedback signal. A difference between the command signal and the feedback signal causes one of the solenoid valves to be activated.

A monitor output is provided for the system measurement. All QBX valves come standard with an analog voltage monitor output. QB1X monitor output is an amplified signal from the internal pressure transducer. QB2X monitor output is a buffered signal from the primary external transducer connected to the QB2X.

INSTALLATION

1. Apply a small amount of anaerobic sealant (provided) to the male threads of the in-line filter supplied with valve.

CAUTION: USE ONLY THE THREAD SEALANT PROVIDED. OTHER SEALANTS SUCH AS PTFE TAPE AND PIPE DOPE CAN MIGRATE INTO THE FLUID SYSTEM CAUSING FAILURES.

2. Install the in-line filter into the port labeled **I** on QBX valve.
3. For vacuum or vacuum through positive pressure units, the vacuum supply should be connected to the exhaust port of the QBX.
4. Connect supply line to the in-line filter port. Connect device being controlled to port labeled **O** on QBX valve.
5. For QBX, there are two output ports; one on the size of the manifold and one on bottom. The working port should be determined when ordering; check to ensure that the other port is plugged.
6. Mount valve accordingly.
7. The valve can be mounted in any position without affecting performance. Mounting bracket QBT-01 (ordered separately) can be used to attach valve to a panel or wall surface.
8. Proceed with electrical connections.

QBX
Electro-Pneumatic Pressure Regulator

SPECIFICATIONS

ELECTRICAL

SUPPLY VOLTAGE	15-24 VDC
SUPPLY CURRENT	250 mA
COMMAND SIGNAL	0-10 VDC | 4-20 mA
COMMAND SIGNAL IMPEDANCE	VDC=4.75 KΩ | Current=100 Ω
ANALOGE MONITOR SIGNAL	
VOLTAGE	0-10 VDC @ 20 mA max
CURRENT	4-20 mA Sinking (sourcing opt)

MECHANICAL

PRESSURE RANGES	Vacuum - 175 psig
	(760 mmHg (Vac) - 12 Bar)
OUTPUT PRESSURE†	0-100% of range
FLOW RATE	1.2 SCFM @ 100 psig inlet
	(34 L/min @ 6.89 Bar)
Cv CAPACITY	0.04
Min CLOSED END VOLUME	2 in^3
PORT SIZE	1/8” NPT
FILTRATION RECOMMENDED	20 Micron *(included)*
LINEARITY/HYSTERESIS	<±0.15% F.S. BFSL
REPEATABILITY	<±0.02% F.S.
ACCURACY	<±0.2% F.S.
WETTED PARTS ‡	
ELASTOMERS	Fluorocarbon
MANIFOLD	Aluminum
VALVES	Nickel Plated Brass
PRESSURE TRANSDUCER	Silicon, Aluminum

PHYSICAL

OPERATING TEMERPATURE	32-158°F *(0-70°C)*
WEIGHT	1.02 lb. *(0.50 Kg)*
PROTECTION RATING	IP 65
HOUSING	Aluminum
FINISH	Black Anodized

† Pressure ranges are customer specified. Output pressures other than 100% are available. ‡ Others available

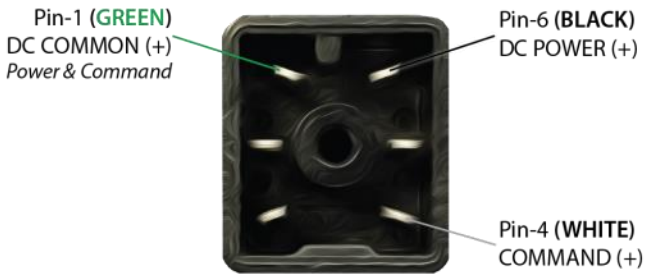
ELECTRICAL CONNECTIONS

1. Turn off all power to valve.
2. Identify the valve's command input and analog output using the calibration card included in the package and the ordering information section on the last page of this sheet.
3. Proceed to the appropriate section corresponding to the type of valve being installed.

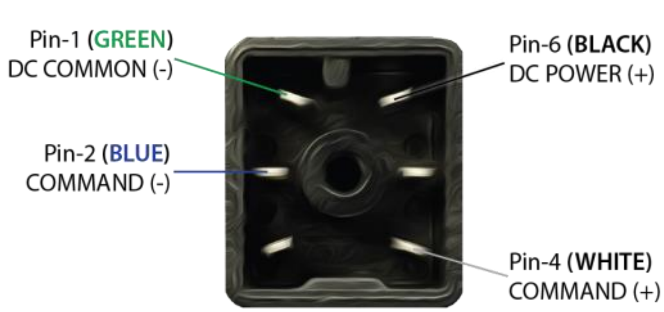
NOTE: ALL COLOR CODES RELATE TO THE FACTORY WIRED QBT POWER CORD.

COMMAND SIGNAL CONFIGURATIONS

VOLTAGE COMMAND VALVES (E, K, V)

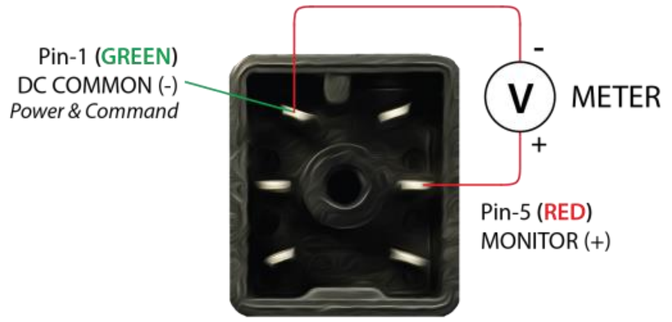


CURRENT COMMAND VALVES (I)

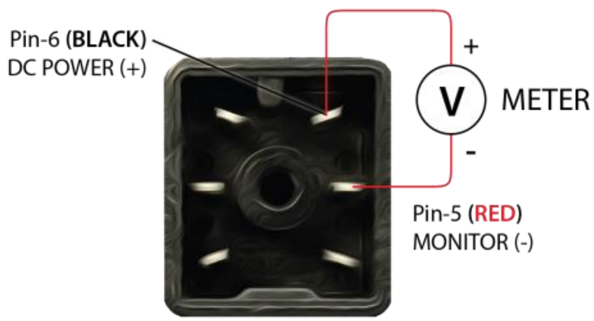


MONITOR SIGNAL CONFIGURATIONS

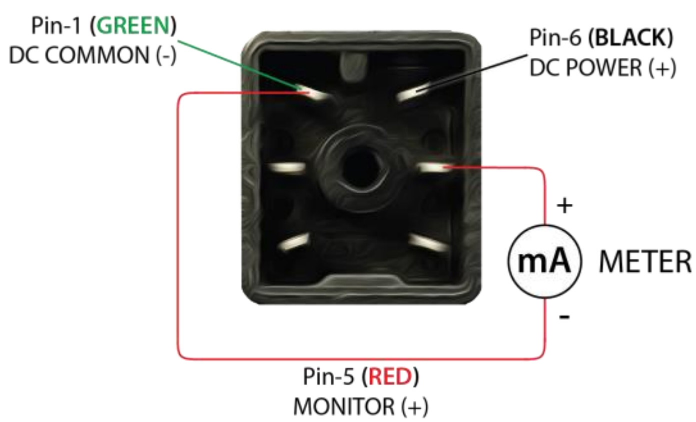
Voltage Monitor (IE or EE)



CURRENT Sinking Monitor (EC or IC)



CURRENT Sourcing Monitor (ES or IS)



QB2X

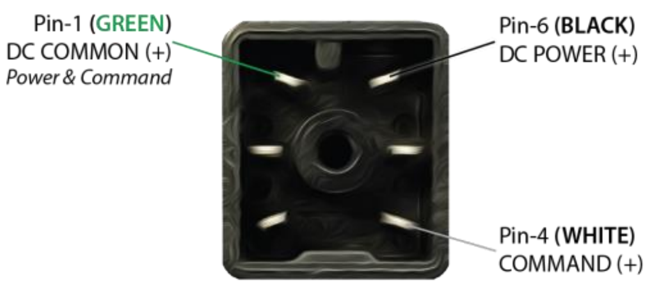
ELECTRICAL CONNECTIONS

1. Turn off all power to valve.
2. Identify the valve's command input and analog output using the calibration card included in the package and the ordering information section on the last page of this sheet.
3. Proceed to the appropriate section corresponding to the type of valve being installed.

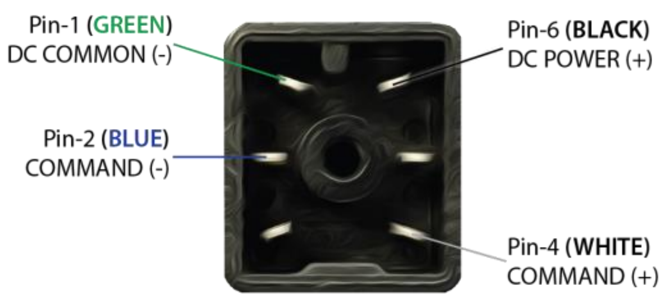
NOTE: ALL COLOR CODES RELATE TO THE FACTORY WIRED QBT POWER CORD.

COMMAND SIGNAL CONFIGURATIONS

VOLTAGE COMMAND VALVES (E, K, V)



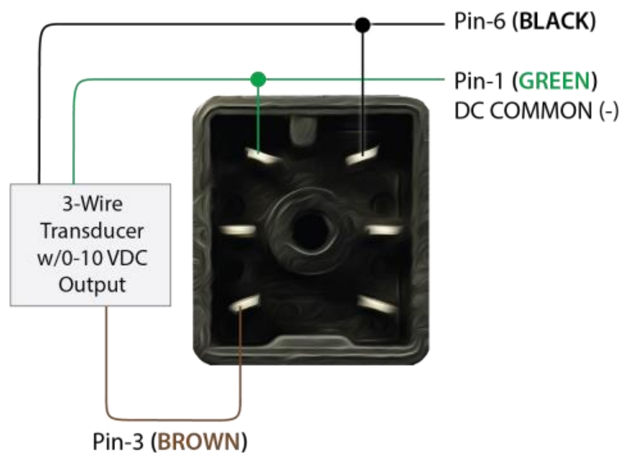
CURRENT COMMAND VALVES (I)



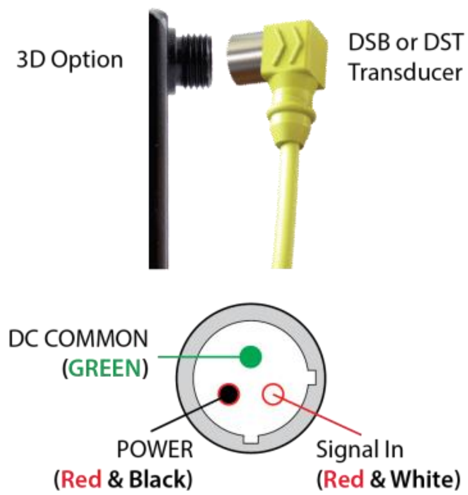
QB2X SECOND LOOP CONNECTIONS

All QB2 valves are *designed to accept a 0-10 volt* second loop input signal, unless ordered with special option code *C2 (4-20 mA second loop input)*. Reference the following wiring diagrams for details.

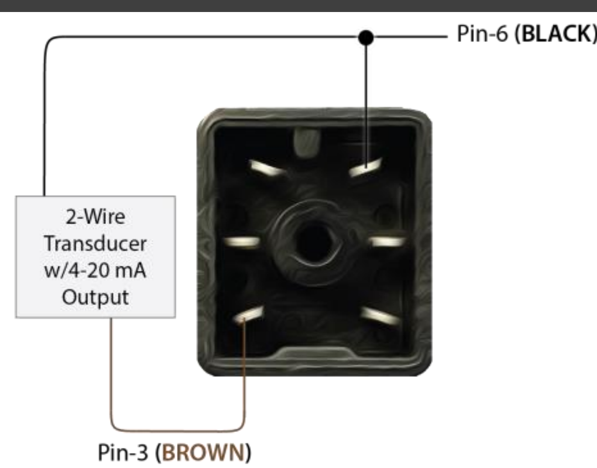
QB2X without 3D Option



QB2X with 3D Option



QB2X with C2 Option *(mA 2nd loop feedback)*



RE-CALIBRATION PROCEDURE

All QBX control valves come calibrated from the factory by trained personnel using precision calibration equipment. The QBX valve is a closed loop control valve using a precision electronic pressure sensor. Typical drift is less than 1% over the life of the product. If your QBX valve appears to be out of calibration by more than 1%, it is not likely to be QBX. Check the system for plumbing leakage, wiring and electronic signal levels. Verify the accuracy of your measuring equipment before re-calibrating. Consult factory if you have any questions or require assistance. If the QBX valve needs re-calibration, use the procedure described below:

QB1X VALVES

1. Identify the inputs and outputs of the valve using the model number of the valve, calibration card included with the valve, and the information provided in this sheet.
2. Connect a precision measuring gage or pressure transducer to the OUT port of the QBX.
   NOTE: THERE MUST BE A CLOSED VOLUME OF AT LEAST 1 CU. IN. (17 CC) BETWEEN THE VALVE OUTLET AND THE MEASURING DEVICE FOR THE VALVE TO BE STABLE.
3. Connect the correct supply source to the IN port of the QBX, making sure the pressure does not exceed the rating for the valve (See Table 1).
4. Locate the plastic calibration access cap on top of the QBX valve and completely remove it. Located underneath are two adjustment trim pots, Zero "Z" and Span "S". See figure 1 for pots location.
5. NOTE: Only use this step if your device is totally out of calibration. If it is slightly out of calibration, omit this step and move on to paragraph 6. Using a small screwdriver, turn both trim pots 15 turns clockwise. Then turn both trim pots 7 turns counterclockwise. This will put the QB roughly at mid-scale.
6. Make correct electrical connections as noted. Make sure there is a proper meter in place to measure the command input to the QBX.
7. Set the electrical command input to MAXIMUM value.
8. Adjust the SPAN pot until MAXIMUM desired pressure is reached (clockwise *increases* pressure).
9. Set the electrical command input to MINIMUM value.
10. Adjust the ZERO pot until MINIMUM desired pressure is reached (clockwise *increases* pressure).
11. Repeat ZERO and SPAN adjustments, which interact slightly, until QB1 valve is calibrated back to proper range. Step 6 - 9.
12. Replace calibration access cap.

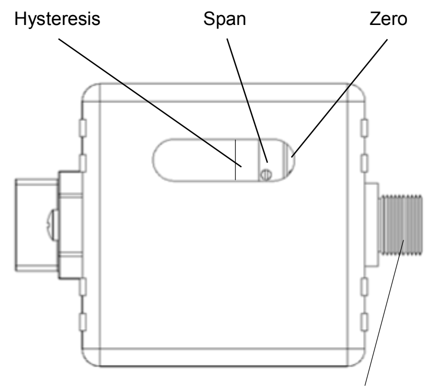


FIGURE 1 *(QB2X, shown with 3D option)*

QB2X VALVES

This section assumes there is a properly scaled and calibrated transducer for use as 2nd loop feedback signal. For information on re-calibrating Proportion-Air DS series pressure transducers see sheet DS-Installation.pdf

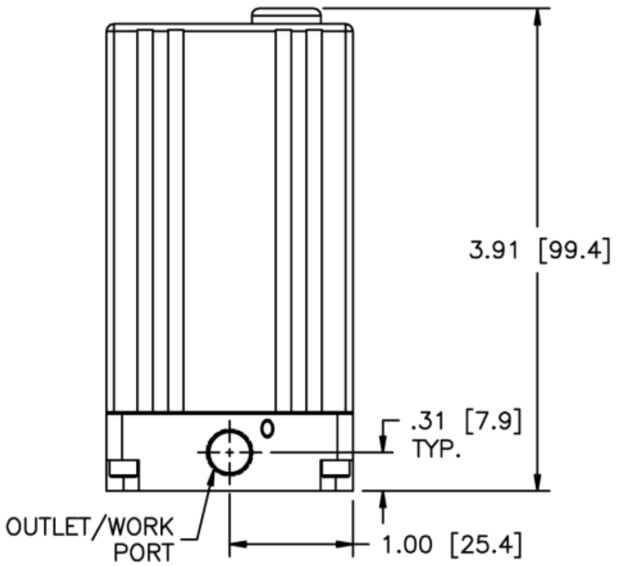
1. Follow, in order, steps 1-5 as noted in the section titled QB1X VALVES .
2. Make correct electrical connections as noted. Make sure there is a proper meter in place to measure the command input to the QB2X. Make sure the 2nd loop signal is connected.
3. Set the electrical command input to MAXIMUM value.
4. Adjust the SPAN pot until MAXIMUM desired pressure is reached (clockwise *increases* pressure).
5. Set the electrical command input to MINIMUM value.
6. Adjust the ZERO pot until MINIMUM desired pressure is reached (clockwise *increases* pressure).
7. Repeat ZERO and SPAN adjustments, which interact slightly, until QB2X valve is calibrated back to proper range. Steps 3 - 6.
8. Replace calibration access cap.

RATED INLET PRESSURE FOR STANDARD QBX VALVES

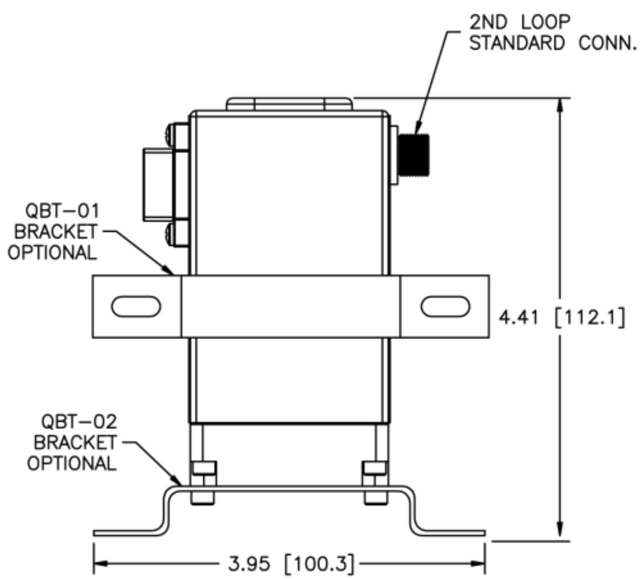
TABLE 1

MAX. calibrated pressure	Max. inlet pressure
Vacuum up to 10 psig *(0.69 bar)*	Consult Factory
10.1 up to 30 psig *(0.70 up to 2 bar)*	35 psig *(2.4 bar)*
31 up to 100 psi *(2.1 up to 7 bar)*	110 psig *(7.6 bar)*
101 up to 150 psig *(7 up to 10.3 bar)*	175 psig *(12 bar)*

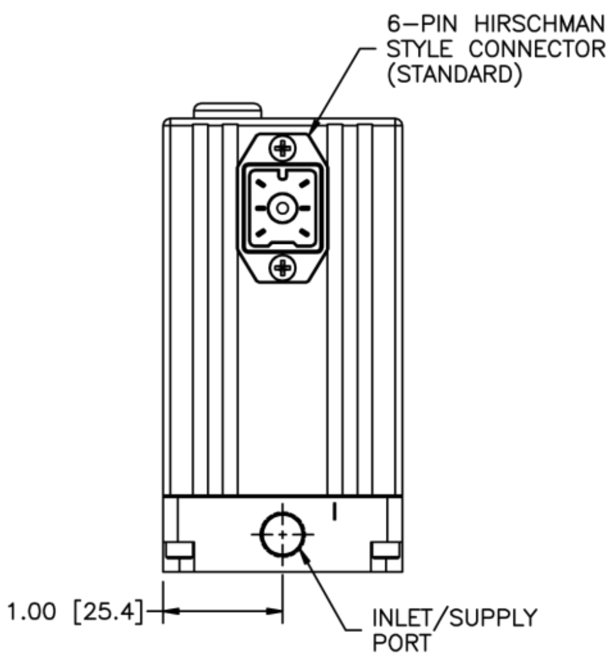
DIMENSIONS



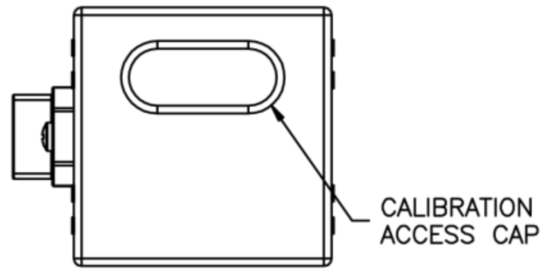
3.91 [99.4]
O
.31 [7.9]
TYP.
OUTLET/WORK
PORT
1.00 [25.4]



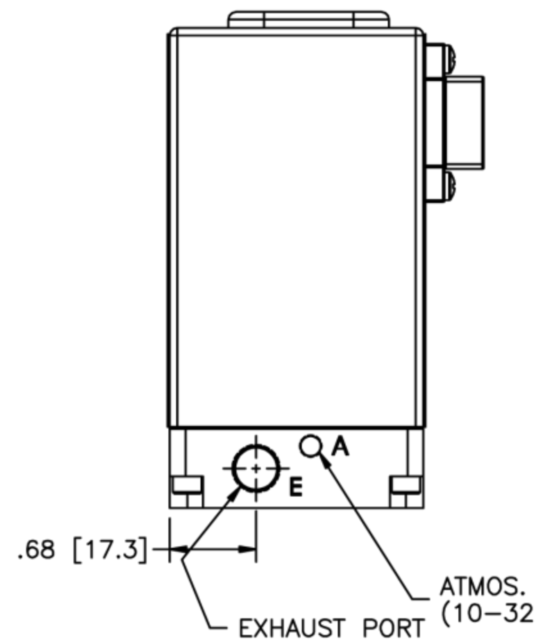
2ND LOOP
STANDARD CONN.
QBT-01
BRACKET
OPTIONAL
4.41 [112.1]
QBT-02
BRACKET
OPTIONAL
3.95 [100.3]



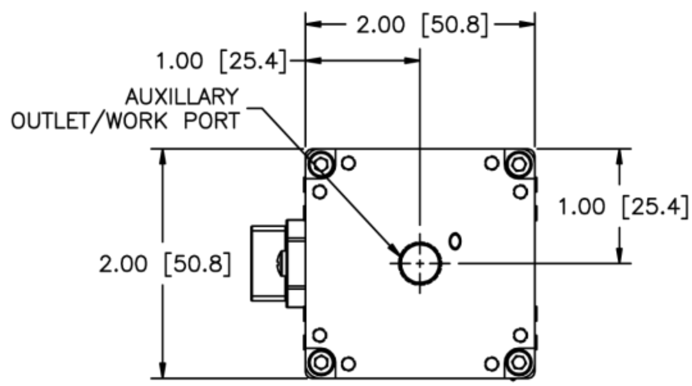
6-PIN HIRSCHMAN
STYLE CONNECTOR
(STANDARD)
I
1.00 [25.4]
INLET/SUPPLY
PORT



CALIBRATION
ACCESS CAP



A
E
.68 [17.3]
ATMOS.
(10-32
EXHAUST PORT



2.00 [50.8]
1.00 [25.4]
AUXILLARY
OUTLET/WORK PORT
1.00 [25.4]
O
2.00 [50.8]

QBX

ACCURACY	±0.2% F.S.	PRESSURE	Full Vac to 175 PSIG *(12 Bar)*
PORT SIZE	1/8"	MAX FLOW	1.2 SCFM *(34 SLPM)*

Example Part Number

QB	2	X	A	N	E	E	N	1	P	6	BR	G	3D	TF
	1		2	3	4	5	6	7	8	9	10	11	OPTIONS	

Section Reference

1	Type
1	Single Loop
2	Dual Loop

2	Manifold Material
A	Anodized Aluminum
B	Brass*
	*Includes O2 Cleaning

3	Thread Type
N	NPT
P	BSPP

4	Input Signal Range
E	0 to 10 VDC
I	4 to 20 mADC
K	0 to 5 VDC
V	1 to 5 VDC *(Requires **V** for Monitor Signal #5)*
D	0 to 255 Bit Digital *(Cannot Select **V** for Monitor Signal #5)*
L	0 to 255 Bit Digital Latching *(Cannot Select **V** for Monitor Signal #5)*
N	Ethernet/Proportion-Air *(Requires **X** for Monitor Signal #5)*
M	Ethernet/MODBUS TCP *(Requires **X** for Monitor Signal #5)*
A	RS232 Serial Input *(Requires **X** for Monitor Signal #5)*
B	RS485 Serial Input *(Requires **X** for Monitor Signal #5)*
P	P2 Profiler *(Integrated)*

5	Output Signal Range
X	No Monitor
E	0 to 10 VDC
K	0 to 5 VDC*
V	1 to 5 VDC*¹
C	4 to 20 mADC *(Sinking)*
S	4 to 20 mADC *(Sourcing)*
	*Requires **E**, **I** or **K** for Input Signal Range (#4)
	*¹Requires **V** for Input Signal Range (#4)

6	Zero Offset
N	0% Pressure is Below Zero
P	0% Pressure is Above Zero
Z	0% Pressure is Zero *(Typical)*

7	Zero Offset Pressure
	Typical is 0* - If greater than 30% of full scale pressure *(#9 below)*, please consult factory.
	*If **Z** for Zero Offset, Please Leave this Section (#7) Blank

8	Full Scale Pressure Type
N	100% Pressure is Below Zero
P	100% Pressure is Above Zero
Z	100% Pressure is Zero

9	Full Scale Pressure
	Must be less than or equal to 175 psig

10	Pressure Unit *(no additional fee - all)*		
PS	PSI	Inches Hg	IH
MB	Millibars	Inches H_2O	IW
BR	Bar	Millimeters H_2O	MW
KP	Kilo-pascal	Kilograms/cm²	KG
MP	Mega-pascal	Torr *(Requires A for Unit of Measure #11)*	TR
MH	Millimeters Hg	Centimeters H_2O	CW
PA	Pascal		

11	Pressure Unit of Measure
A	Absolute Pressure
G	Gauge Pressure
D	Differential Pressure

Safety Precautions

Please read all of the following Safety Precautions before installing or operating any Proportion-Air, Inc. equipment or accessories. To confirm safety, be sure to observe 'ISO 4414: Pneumatic Fluid Power - General rules relating to systems' and other safety practices.

Warning

Improper operation could result in serious injury to persons or loss of life!

1. **PRODUCT COMPATIBILITY**
   Proportion-Air, Inc. products and accessories are for use in industrial pneumatic applications with compressed air media. The compatibility of the equipment is the responsibility of the end user. Product performance and safety are the responsibility of the person who determined the compatibility of the system. Also, this person is responsible for continuously reviewing the suitability of the products specified for the system, referencing the latest catalog, installation manual, Safety Precautions and all materials related to the product.
2. **EMERGENCY SHUTOFF**
   Proportion-Air, Inc. products cannot be used as an emergency shutoff. A redundant safety system should be installed in the system to prevent serious injury or loss of life.
3. **EXPLOSIVE ATMOSPHERES**
   Products and equipment should not be used where harmful, corrosive or explosive materials or gases are present. Unless certified, Proportion-Air, Inc. products cannot be used with flammable gases or in hazardous environments.
4. **AIR QUALITY**
   Clean, dry air is not required for Proportion-Air, Inc. products. However, a 40 micron particulate filter is recommended to prevent solid contamination from entering the product.
5. **TEMPERATURE**
   Products should be used with a media and ambient environment inside of the specified temperature range of 32°F to 158°F. Consult factory for expanded temperature ranges.
6. **OPERATION**
   Only trained and certified personnel should operate electronic and pneumatic machinery and equipment. Electronics and pneumatics are very dangerous when handled incorrectly. All industry standard safety guidelines should be observed.
7. **SERVICE AND MAINTENANCE**
   Service and maintenance of machinery and equipment should only be handled by trained and experienced operators. Inspection should only be performed after safety has been confirmed. Ensure all supply pressure has been exhausted and residual energy (compressed gas, springs, gravity, etc.) has been released in the entire system prior to removing equipment for service or maintenance.

Caution

Improper operation could result in serious injury to persons or damages to equipment!

1. **PNEUMATIC CONNECTION**
   All pipes, pneumatic hose and tubing should be free of all contamination, debris and chips prior to installation. Flush pipes with compressed air to remove any loose particles.
2. **THREAD SEALANT**
   To prevent product contamination, thread tape is not recommended. Instead, a non-migrating thread sealant is recommended for installation. Apply sealant a couple threads from the end of the pipe thread to prevent contamination.
3. **ELECTRICAL CONNECTION**
   To prevent electronic damage, all electrical specifications should be reviewed and all electrical connections should be verified prior to operation.

Exemption from Liability

1. **Proportion-Air, Inc.** is exempted from any damages resulting from any operations not contained within the catalogs and/or instruction manuals and operations outside the range of its product specifications.
2. **Proportion-Air, Inc.** is exempted from any damage or loss whatsoever caused by malfunctions of its products when combined with other devices or software.
3. **Proportion-Air, Inc.** and its employees shall be exempted from any damage or loss resulting from earthquakes, fire, third person actions, accidents, intentional or unintentional operator error, product misapplication or irregular operating conditions.
4. **Proportion-Air, Inc.** and its employees shall be exempted from any damage or loss, either direct or indirect, including consequential damage or loss, claims, proceedings, demands, costs, expenses, judgments, awards, loss of profits or loss of chance and any other liability whatsoever including legal expenses and costs, which may be suffered or incurred, whether in tort (including negligence), contract, breach of statutory duty, equity or otherwise.

Warranty

Proportion-Air, Inc. products are warranted to the original purchaser only against defects in material or workmanship for one (1) year from the date of manufacture. The extent of Proportion-Air's liability under this warranty is limited to repair or replacement of the defective unit at Proportion-Air's option. Proportion-Air shall have no liability under this warranty where improper installation or filtration occurred.